Table 19. VACUUM FILTRATION TESTING RESULTS FOR KENOSHA, WI, CONTACT STABILIZATION SLUDGE

Feed solids concentration: 3.1%

Chemical dosage, kg/m ton		Cycle time, min	Pickup time, sec	Dry time, sec	Submergence, %	Yield, $kg/hr/m^2$	Loading, kg/m^2	Cake solids, %	Filtrate solids, mg/l	Filtrate volume, ml	Type of cloth	Cake Discharge character-istics
$FeCl_3$	CaO											
60	128	4	60	120	25	14.3	0.98	14.9	3,850	310	2x2 twill olefin multifilament	Poor
60	128	3	45	90	25	18.0	0.88	15.16	1,560	220	2x2 twill olefin multifilament	Poor
60	128	4	60	120	25	15.8	1 07	14.89	88	428	Napped 1x5 olefin spun staple	Poor
60	128	4	60	120	25	15.6	1.02	13.94	60	460	Napped 1x5 olefin spun staple	Poor
60	128	3	45	90	25	18.0	0.88	15 16	82	360	Napped 1x5 olefin spun staple	Poor
60	128	4	60	120	25	13.1	0.88	16.55	92	290	1x4 satin nylon multifilament	Good
60	128	3	45	90	25	18.2	0.93	14.28	45	235	1x4 satin nylon multifilament	Excellent
60	128	4	90	120	25	17.1	1.12	13.33	--	295	1x4 satin nylon multifilament	Good
60	128	3	65	75	37.5	19.8	0.98	11.89	--	270	1x4 satin nylon multifilament	Good
60	128	4	60	120	25	14.2	0.93	13.95	10	240	1x4 satin nylon multifilament	Excellent
60	128	3	45	90	25	11.2	0.93	13.09	--	200	1x4 satin nylon multifilament	Good
60	128	3	45	90	25	17.6	0.88	15.36	--	210	1x4 satin nylon multifilament	Good

Table 18. CENTRIFUGE TESTING RESULTS FOR KENOSHA, WI, CONTACT STABILIZATION SLUDGE

Test No.	Applied G force, "G's"	Spin time, sec	Feed solids, mg/l	Chemical	Dosage, kg/m ton	Centrate solids, mg/l	Centrate volume, ml	Penetration, cm	Sludge depth, cm	Cake solids, %	Penetration, %	Recovery, %	Corrected recovery, %
1	400	60	8,413	none	none	--	--	7.8	7.8	--	0	--	0[a]
2	750	60	8,413	none	none	--	68.3	2.2	2.2	--	0	--	0
3	1,000	60	8,413	none	none	--	64.0	1.9	1.9	--	0	--	0
4	1,000	90	8,413	none	none	134	64.0	7.9	7.9	5.6	0	98.4	0
5	750	90	8,413	none	none	132	62.5	1.9	1.9	5.2	0	98.4	0
6	400	120	8,413	none	none	--	70.8	9.75	9.75	--	0	--	0
7	750	120	8,413	none	none	140	63.0	1.84	1.84	5.7	0	98.3	0
8	1,000	120	8,413	none	none	54	64.0	1.75	1.75	8.9	0	99.3	0
9	1,000	120	8,413	C31	12.05	96	68.0	1.5	1.5	8.0	0	98.8	0
10	750	120	8,413	C31	12.05	79	67.2	1.65	1.65	2.1	0	99.0	0
11	750	120	8,413	C31	7.81	90	44.5	3.84	3.84	6.1	0	98.9	0
12	400	120	8,413	C31	12.05	77	64.8	1.9	1.9	5.6	0	99.1	0
13	400	60	25,850	none	none	--	--	8.5	8.5	--	0	--	0
14	750	60	25,850	none	none	--	61.5	7.25	7.25	--	0	--	0
15	1,000	60	25,850	none	none	--	67.5	6.5	6.5	--	0	--	0
16	1,000	90	25,850	none	none	12,900	52.5	5.68	5.68	6.2	0	49.6	0
17	750	90	28,850	none	none	14,725	57.2	5.97	5.97	6.0	0	42.5	0
18	400	120	25,850	none	none	--	60.5	4.9	4.9	--	0	--	0
19	750	120	25,850	none	none	12,195	53.5	6.78	6.78	6.0	0	52.4	0
20	1,000	120	25,850	none	none	7,790	49.0	4.4	4.4	6.0	0	69.6	0
21	1,000	120	25,850	C31	7.81	107	45.8	3.73	3.73	6.6	0	99.6	0
22	400	120	25,850	C31	7.81	7,350	44.5	7.02	7.02	5.2	0	71.3	0
23	400	120	25,850	C31	7.81	206	40.0	7.65	7.65	5.5	0	99.2	0
24	1,000	120	25,850	C31	11.72	160	41.5	7.5	7.5	5.8	0	99.4	0

a. Denotes poor scrollability of the thickened sludge. See Appendix B for procedure.

Table 19. VACUUM FILTRATION TESTING RESULTS FOR KENOSHA, WI, CONTACT STABILIZATION SLUDGE

Feed solids concentration: 3.1%

Chemical dosage, kg/m ton		Cycle time, min	Pickup time, sec	Dry time, sec	Submergence, %	Yield, kg/hr/m^2	Loading, kg/m^2	Cake solids, %	Filtrate solids, mg/l	Filtrate volume, ml	Type of cloth	Cake Discharge character-istics
$FeCl_3$	CaO											
60	128	4	60	120	25	14.3	0.98	14.9	3,850	310	2x2 twill olefin multifilament	Poor
60	128	3	45	90	25	18.0	0.88	15.16	1,560	220	2x2 twill olefin multifilament	Poor
60	128	4	60	120	25	15.8	1 07	14.89	88	428	Napped 1x5 olefin spun staple	Poor
60	128	4	60	120	25	15.6	1.02	13.94	60	460	Napped 1x5 olefin spun staple	Poor
60	128	3	45	90	25	18.0	0.88	15.16	82	360	Napped 1x5 olefin spun staple	Poor
60	128	4	60	120	25	13.1	0.88	16 55	92	290	1x4 satin nylon multifilament	Good
60	128	3	45	90	25	18.2	0.93	14.28	45	235	1x4 satin nylon multifilament	Excellent
60	128	4	90	120	25	17.1	1.12	13.33	--	295	1x4 satin nylon multifilament	Good
60	128	3	65	75	37.5	19.8	0.98	11.89	--	270	1x4 satin nylon multifilament	Good
60	128	4	60	120	25	14.2	0.93	13.95	10	240	1x4 satin nylon multifilament	Excellent
60	128	3	45	90	25	11.2	0.93	13.09	--	200	1x4 satin nylon multifilament	Good
60	128	3	45	90	25	17.6	0.88	15.36	--	210	1x4 satin nylon multifilament	Good

New Providence, NJ

This treatment facility utilizes trickling filters for the treatment of dry-weather flow as well as large quantities of polluted water during wet-weather periods generated by infiltration to the sewer system. Dewatering tests were conducted on separate sludge samples from the primary and secondary clarifier during both the wet and dry-weather periods.

Wet-Weather Sludge Samples - A schematic of the dewatering techniques investigated on wet-weather samples is shown in Figure 26. The total quantity of the primary sludge during wet-weather is 735 cu m (194,200 gal.) per storm event based on mass balance for a measured sludge concentration of 0.12% solids. However, this low solid strength for a primary sludge probably stems from the unique clarifier operation situation at New Providence whereby a fixed amount of sludge produced per day is sent out for separate treatment and therefore, sludge blanket and strength do not build up in a conventional manner. If this underflow is compared to a conventional situation, assuming 4% solids (21,22), approximately 22 cu m (5,800 gal.) of sludge would be produced. The quantity of sludge produced from secondary clarifier was estimated at approximately 62 cu m (16,380 gal.) per storm event. The measured solids concentration of the secondary sludge sample procured was 2.5%.

The flux concentration curves for the gravity thickening tests for the primary and secondary samples are shown in Figures 27 through 30. The dilute primary sludge sample showed amenability to gravity thickening. With the help of flocculating chemicals (lime and anionic polymer), up to 8% solids could be expected at mass loading rates of 500 kg/sq m/day (100 lbs/sq ft/day). Without chemical aids, the results were significantly poorer. Comparitively, the secondary sludge showed poor amenability to gravity thickening as solids concentrations of only 2 to 3% were achieved with or without chemical aids at low loading rates of less than 20 kg/sq m/day (4 lbs/sq ft/day).

The flotation thickening test results are shown in Figures 31 through 33. For primary sludge, again chemicals aided in superior performance and solids concentrations similar to gravity thickening (up to 8%) were achieved at mass loading rates of the order of 250 kg/sq m/day (50 lbs/sq ft/day). The optimum recycle rates were generally less than 160%. For secondary clarifier sludge, the flotation thickening performance was significantly better than gravity thickening as solid concentrations up to 5% without chemicals and up to 6% with chemicals were achieved. With chemical aids (lime and Magnifloc anionic polyelectrolyte 837-A), these concentrations were achieved at significantly higher loading rates of 250 to 350 kg/sq m/day (50 to 10 lbs/sq ft/day) compared to lower loading rates of less than 50 kg/sq m/day (10 lbs/sq ft/day) without chemicals. The optimum recycle rates were between 250 and 300%.

The results of centrifugation tests for the primary and secondary sludge samples are shown in Tables 20 and 21 respectively. The results show poor amenability to centrifugation for the primary sludge sample. Cake

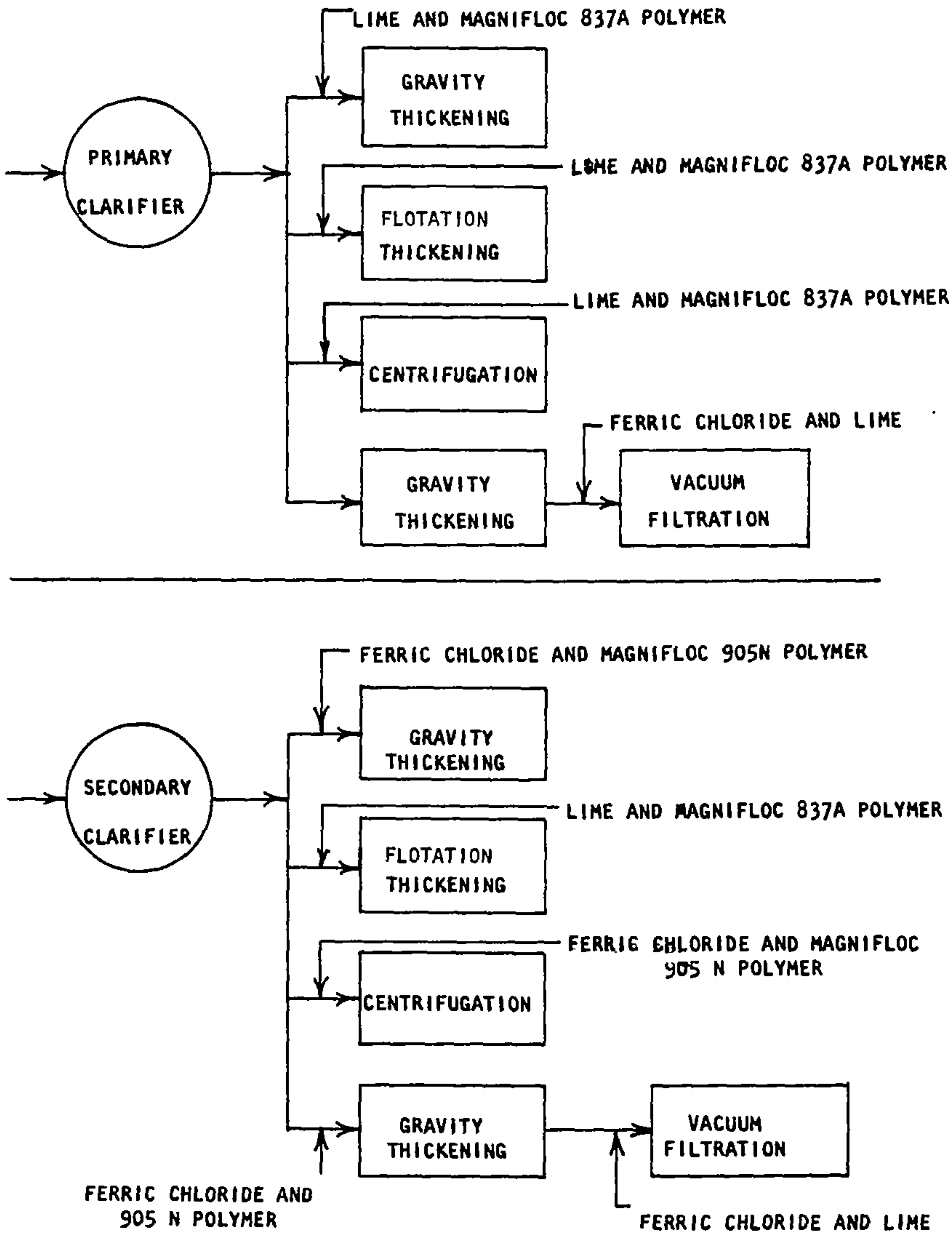

Figure 26. New Providence, NJ - bench scale dewatering tests (wet-weather)

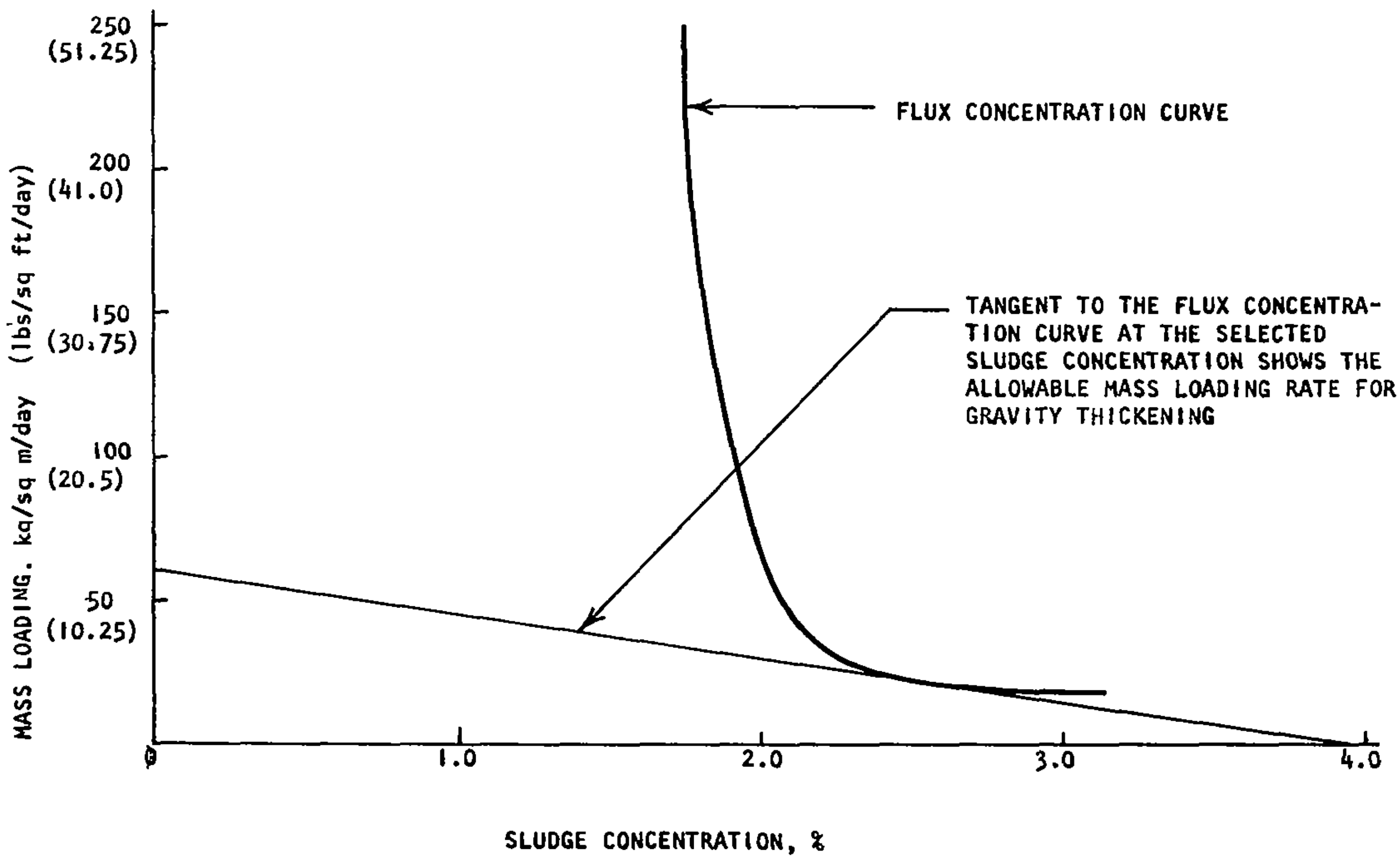

Figure 27. Flux concentration curve for New Providence, NJ, wet-weather trickling filtration primary sludge (without chemicals)

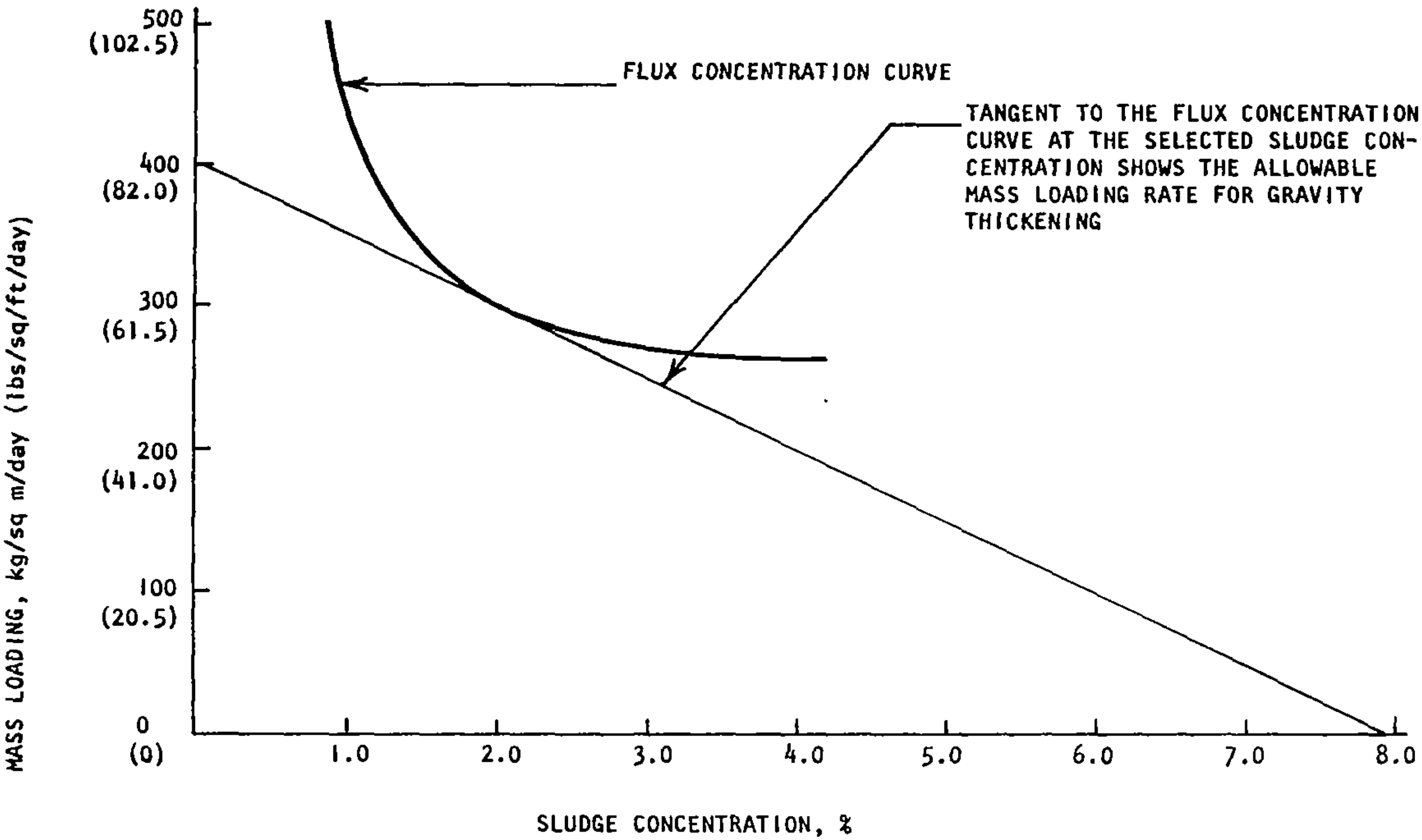

Figure 28. Flux concentration curve for New Providence, NJ, wet-weather trickling filtration primary sludge with chemicals (333 kg/m ton of lime and 5.0 kg/m ton of magnifloc 837A polymer)

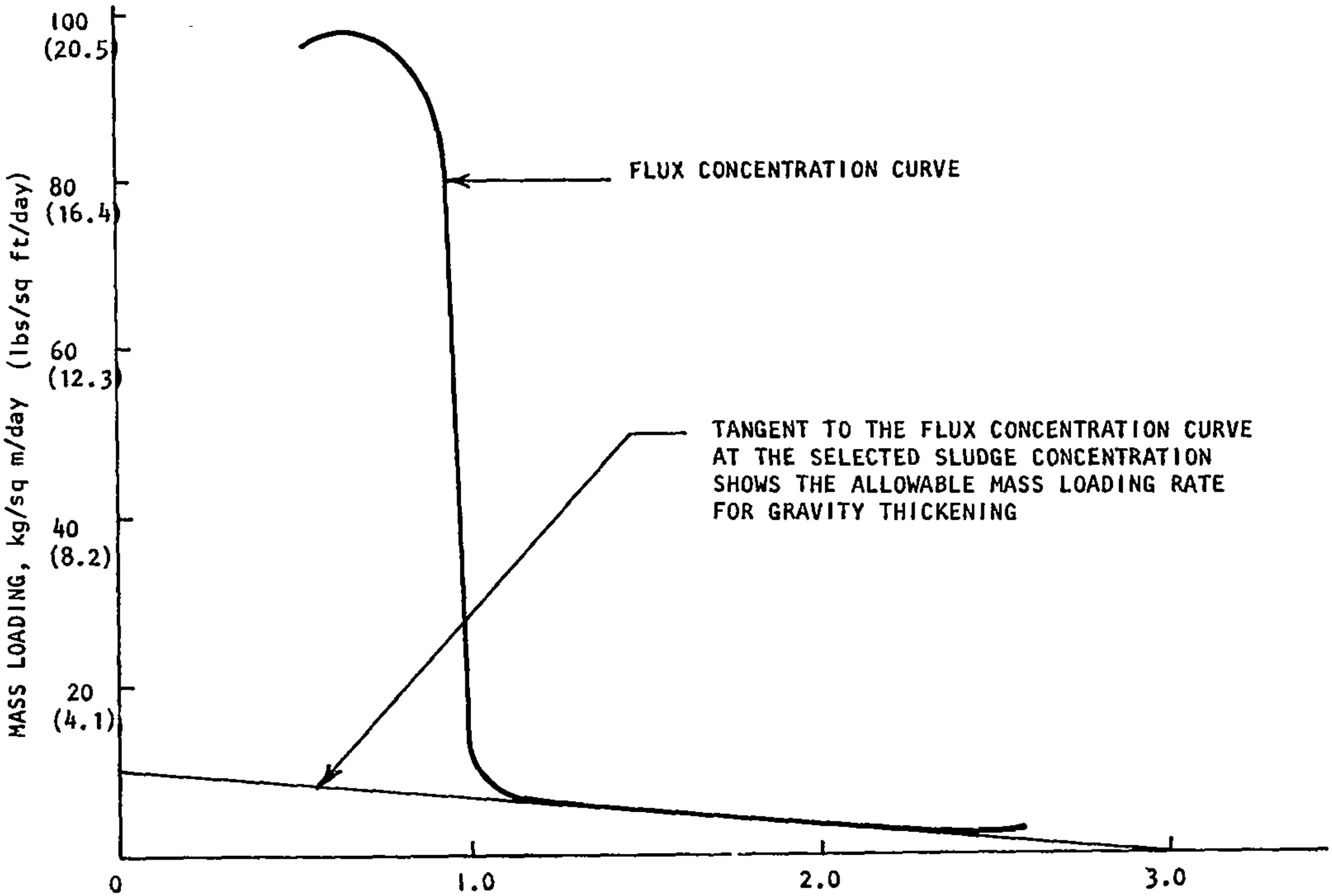

Figure 29. Flux concentration curve for New Providence, NJ, wet-weather secondary sludge (without chemicals)

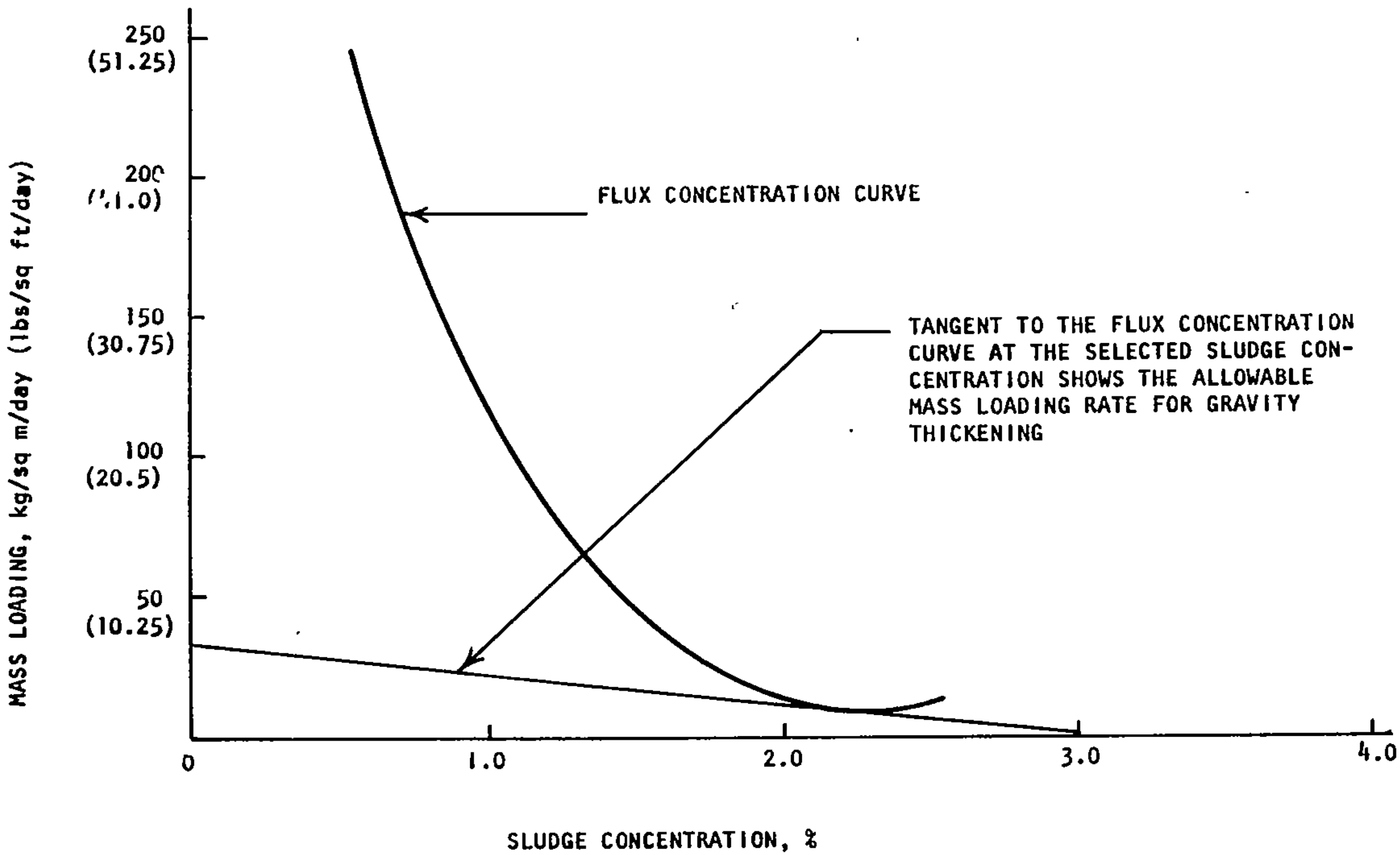

Figure 30. Flux concentration curve for New Providence NJ, wet-weather secondary sludge (with 105 kg/m ton ferric chloride and 2 kg/m ton magniflox 905N polymer)

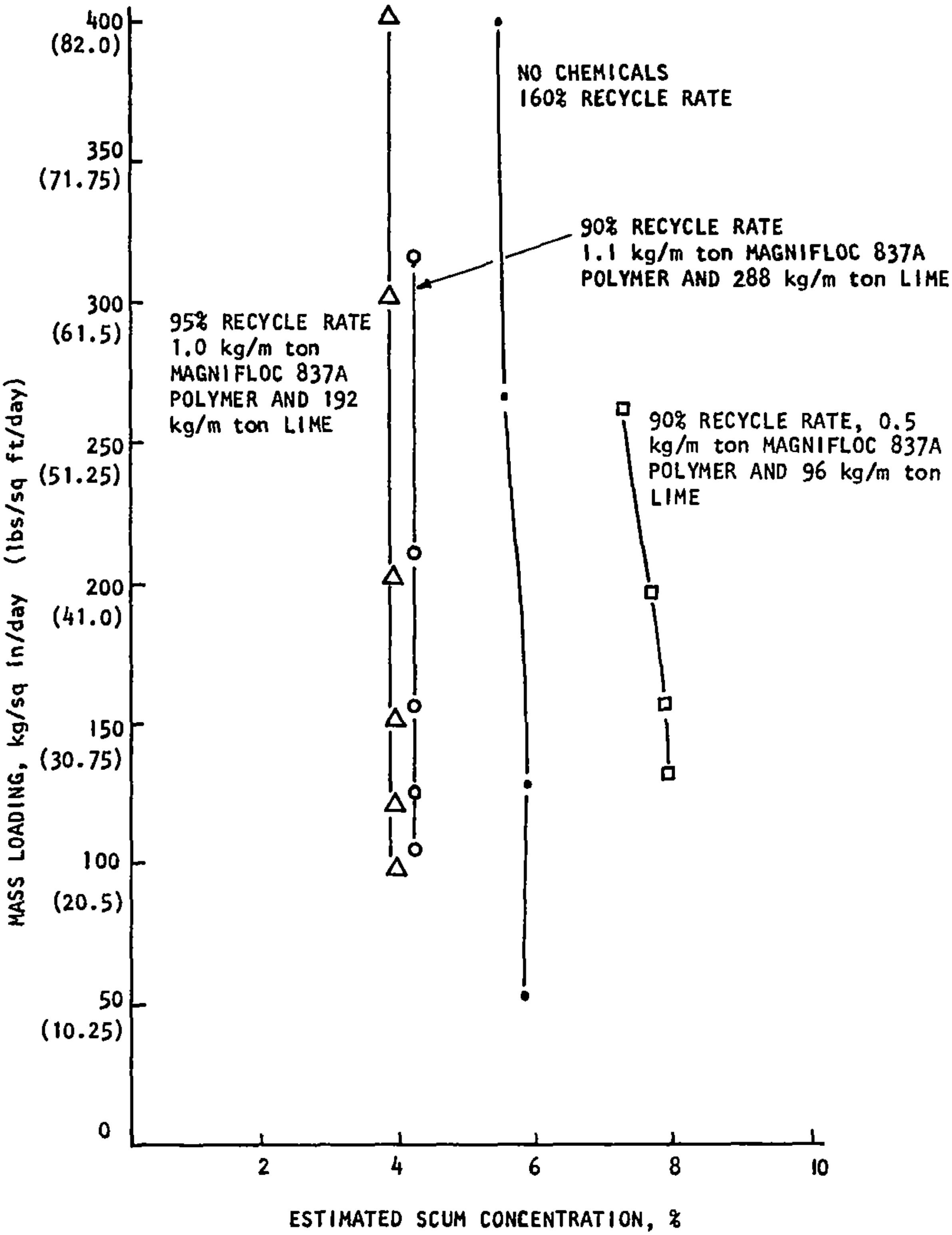

Figure 31. Flotation thickening test results for New Providence, NJ, wet-weather primary sludge

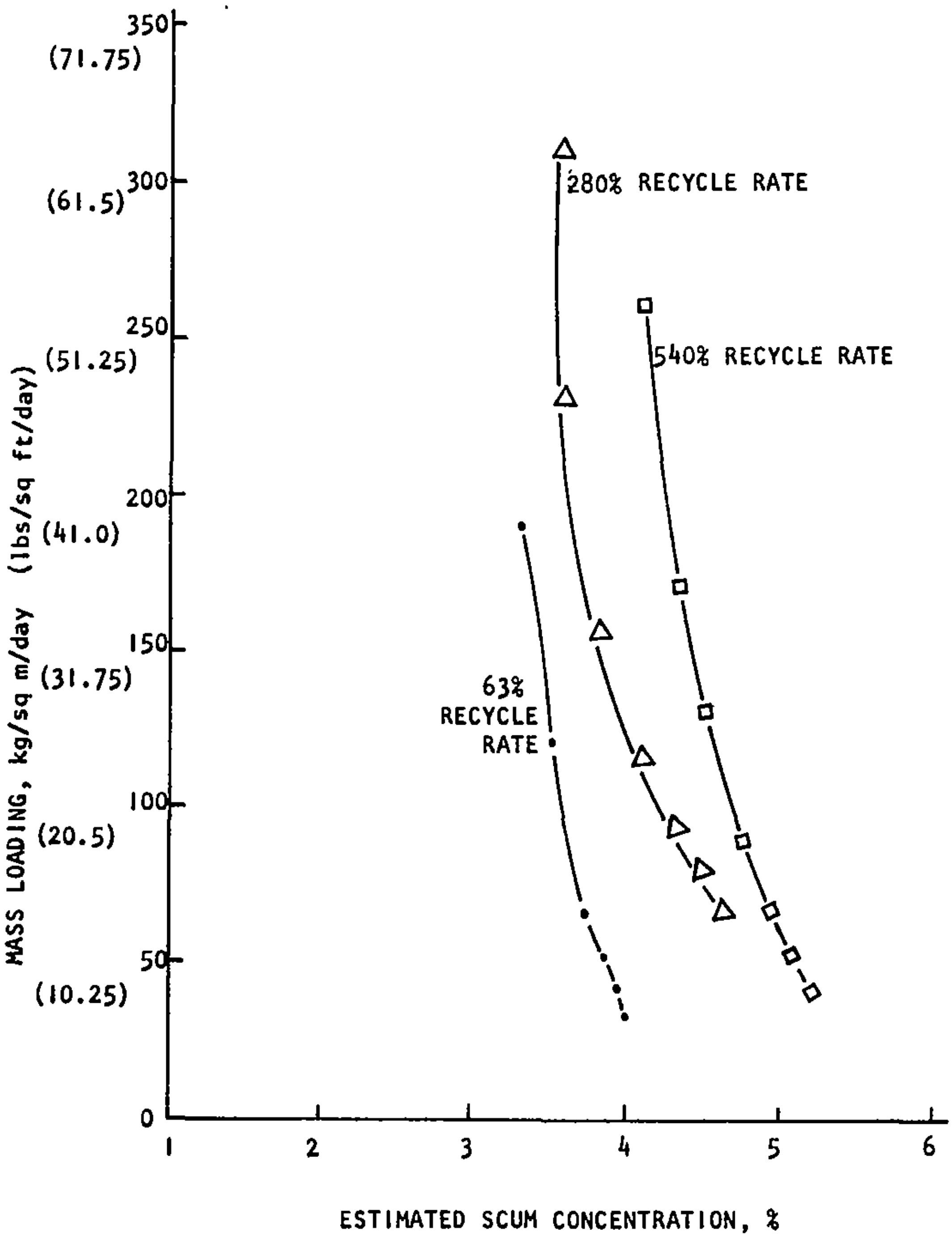

Figure 32. Flotation thickening test results for New Providence, NJ, wet-weather secondary sludge (without chemicals)

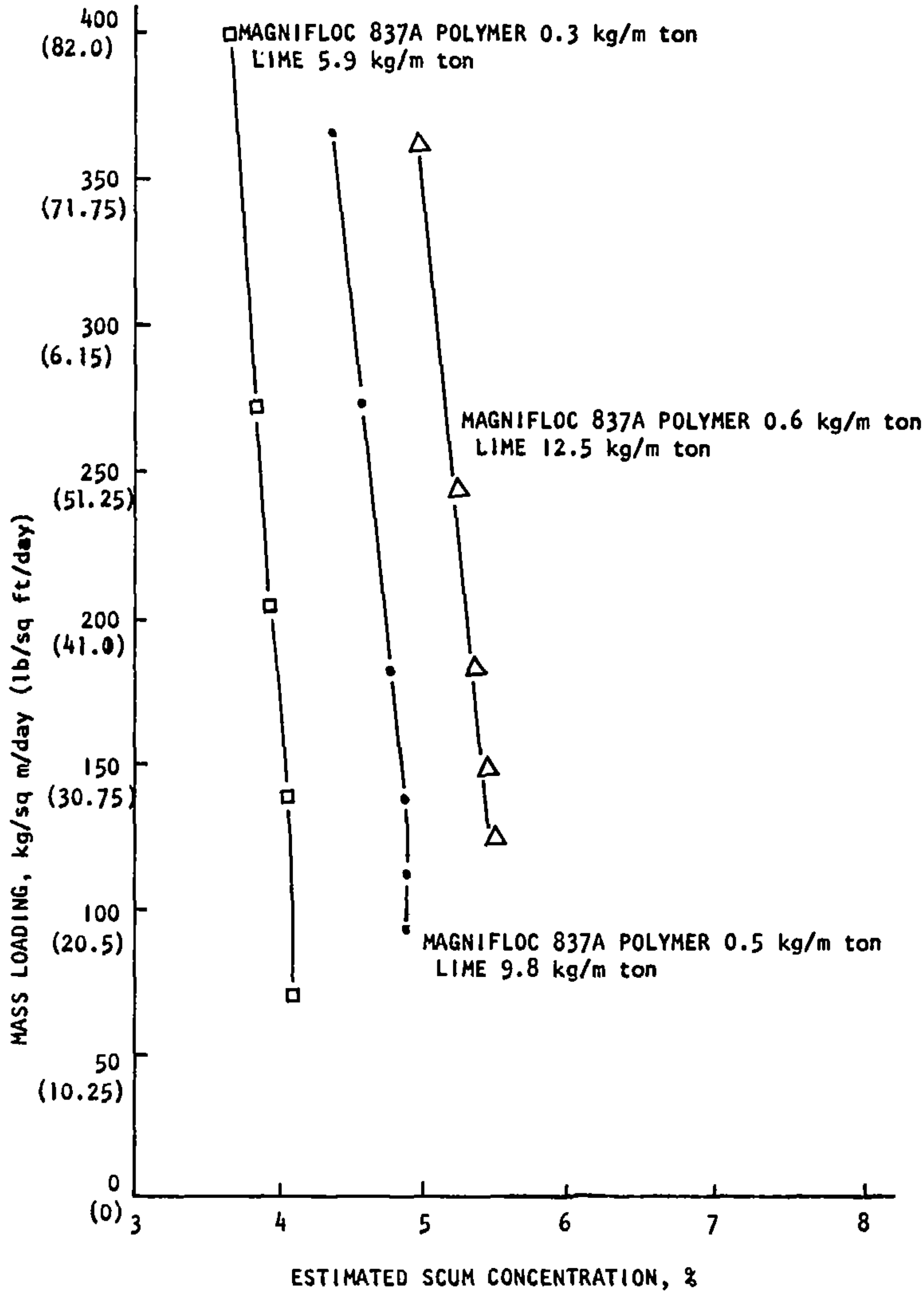

Figure 33. Flotation thickening results for New Providence, NJ, wet-weather secondary sludge (with chemicals)

Table 20. CENTRIFUGE TESTING RESULTS FOR NEW PROVIDENCE, NJ, WET-WEATHER TRICKLING FILTRATION PRIMARY SLUDGE

Test No.	Applied G force, "G's"	Spin time, sec	Feed solids, mg/l	Chemical	Dosage, kg/m ton	Centrate solids, mg/l	Centrate volume, ml	Penetrations, cm	Sludge depth, cm	Cake solids, %	Penetration, %	Recovery, %	Corrected recovery, %
10	1,000	30	1,200	none	none	313	69	0.55	1.5	1.14	63	73.9	70.6
11	1,000	60	1,200	none	none	206	70	0.6	1.15	1.51	48	82.8	76.9
12	1,000	90	1,200	none	none	208	70	0.55	1.3	1.51	58	82.6	78.1
13	1,000	120	1,200	none	none	222	70	0.4	1.35	1.49	70	81.5	78.6
14	700	30	1,200	none	none	550	67	0.7	1.75	0.66	60	54.1	51.4
15	700	60	1,200	none	none	338	69	0.95	1.35	1.11	30	71.8	63.6
16	700	90	1,200	none	none	234	69	0.85	1.6	1.23	47	80.5	74.6
17	700	120	1,200	none	none	340	70	0.65	1.4	1.32	54	71.6	67.2
18	400	30	1,200	none	none	992	69	1.2	1.45	0.36	17	17.3	14.5
19	400	60	1,200	none	none	516	68	0.85	1.5	0.78	43	57.0	52.4
20	400	90	1,200	none	none	449	68	1.0	1.6	0.85	38	62.5	56.7
21	400	120	1,200	none	none	545	67	0.95	1.55	0.68	39	54.5	49.6
22	1,000	30	1,200	837A+CaO	13.4+2,670	320	68	0.4	1.75	0.97	77	73.3	71.4
23	1,000	60	1,200	837A+CaO	13.4+2,670	325	69	0.45	1.65	1.13	73	72.9	70.6
24	1,000	90	1,200	837A+CaO	13.4+2,670	361	67	0.25	1.6	0.82	84	69.9	68.7
25	1,000	120	1,200	837A+CaO	13.4+2,670	200	68	0.35	1.5	1.09	77	83.3	81.1
26	700	30	1,200	837A+CaO	13.4+2,670	207	66	0.4	1.5	0.85	73	82.7	80.0
27	700	60	1,200	837A+CaO	13.4+2,670	216	68	0.5	1.45	1.08	66	82.0	78.6
28	700	90	1,200	837A+CaO	13.4+2,670	215	69	0.4	1.3	1.25	69	82.0	79.0
29	700	120	1,200	837A+CaO	13.4+2,670	212	69	0.5	1.0	1.26	50	82.3	76.7
30	400	30	1,200	837A+CaO	13.4+2,670	237	66	0.5	1.45	1.00	66	80.2	76.9
31	400	60	1,200	837A+CaO	13.4+2,670	187	67	0.55	1.55	0.97	65	84 4	80.8
32	400	90	1,200	837A+CaO	13.4+2,670	162	69	0.55	1.55	1.31	65	86.5	82.8
33	400	120	1,200	837A+CaO	13.4+2,670	178	68	0.55	1.5	1.11	63	85.1	81 3

Table 21. CENTRIFUGE TESTING RESULTS FOR NEW PROVIDENCE, NJ, WET-WEATHER TRICKLING FILTRATION SECONDARY SLUDGE

Test No.	Applied G force, G's	Spin time, sec	Feed solids, mg/l	Chemical	Dosage, kg/m ton	Centrate solids, mg/l	Centrate volume, ml	Penetration, cm	Sludge depth, cm	Cake solids, %	Penetration, %	Recovery, %	Corrected recovery, %
1	1,000	60	25,000	none	none	808	38	4.45	4.45	5.0	0	96.0	0[a]
2	1,000	90	25,000	none	none	528	43	3.7	3.9	5.8	5	97.4	72.3
3	1,000	120	25,000	none	none	658	44	3.3	3.8	6.0	16	97.3	80.8
4	700	60	25,000	none	none	1,380	38	4.65	4.65	4.9	0	94.4	0[a]
5	700	90	25,000	none	none	1,050	39	4.65	4.65	5.1	0	95.8	0[a]
6	700	120	25,000	none	none	637	41	3.65	4.1	5.4	11	97.4	78.0
7	400	60	25,000	none	none	1,480	33	4.95	4.95	4.3	0	94.0	0[a]
8	400	90	25,000	none	none	840	35	4.65	4.65	4.6	0	96.6	0[a]
9	400	120	25,000	none	none	850	36	4.4	4.4	4.7	0	96.6	0[a]
34	1,000	30	25,000	$FeCl_3$+905N	1458+40	174	43	1.65	3.9	5.8	58	99.3	93.9
35	1,000	60	25,000	$FeCl_3$+905N	1458+40	184	46	1.95	3.25	6.4	40	99.2	90.5
36	1,000	90	25,000	$FeCl_3$+905N	1458+40	136	49	1.65	3.45	7.2	52	99.4	93.1
37	1,000	120	25,000	$FeCl_3$+905N	1458+40	169	50	1.75	3.3	7.5	47	99.3	92.1
38	700	30	25,000	$FeCl_3$+905N	1458+40	231	39	2.25	4.3	5.2	48	99.0	91.9
39	700	60	25,000	$FeCl_3$+905N	1453+40	165	44	1.8	3.8	6.0	53	99.3	93.1
40	700	90	25,000	$FeCl_3$+905N	1458+40	190	43	2.3	3.6	5.6	39	99.2	90.4
41	700	120	25,000	$FeCl_3$+905N	1458+40	137	44	2.1	3.65	6.0	42	99.4	91.2
42	400	30	25,000	$FeCl_3$+905N	1458+40	252	37	3.0	4.3	4.9	30	98.9	87.7
43	400	60	25,000	$FeCl_3$+905N	1458+40	119	34	2.6	3.95	4.6	34	99.5	89.4
44	400	90	25,000	$FeCl_3$+905N	1458+40	157	40	2.65	4.05	5.3	34	99.3	89.3
45	400	120	25,000	$FeCl_3$+905N	1453+40	187	43	2.45	3.9	5.8	37	99.2	89.8

a. Denotes poor thickening performance for a scroll type centrifuge. See Appendix B for procedure.

solids of only 2% or less were achieved even with the aid of chemicals. For the secondary sludge, cake solids of approximately 7.5% were achieved with the aid of chemicals (ferric chloride and Magnifloc nonionic polyelectrolyte). Both samples showed poor scrollability and hence basket type centrifuge will be necessary for such sludges. No centrifugation tests were run on gravity thickened primary sludge samples. Based on the results of various other sludges evaluated in this study, it is indicated that significantly better centrifugation results on gravity thickened sludges can be expected.

The vacuum filtration tests on both the primary and secondary sludge samples were conducted on pre-sedimented samples. The feed solids concentrations after sedimentation were 2.5% and 3.2% for the two samples respectively. The test results are shown in Tables 22 and 23 respectively. Based on the results of the Buchner Funnel tests, a combination of ferric chloride and lime showed best filtration results for both sludge samples. Best cake discharge characteristics were obtained with multifilament polypropylene filter cloth. Cake solids of nearly 28% were achieved for the primary sludge, while solids concentrations of only 16 to 18% were achieved for the secondary sludge samples under optimum test conditions. The optimum filter yields for the two samples were approximately 18 kg/sq m/hr (3.5 lbs/sq ft/hr).

Dry-Weather Sludge Samples - A schematic of the dewatering techniques investigated on the dry-weather sludge samples from the primary and secondary clarifiers is shown in Figure 34. The present quantities of sludge being discharged from primary and secondary clarifiers are 68 cu m (26,150 gal.) per day respectively (Table 2). As mentioned earlier, these quantities are presently discharged without regard to the sludge strength. Both sludge samples procured for dewatering tests showed low solids concentrations of 0.38 and 0.46 respectively.

The flux concentration curves for the gravity thickening tests on the two samples are shown in Figures 35 and 36. Both these curves represent the test data without the addition of any flocculating chemicals. It was found that flocculating chemicals did not provide any improvement in the gravity thickening performance. For primary sludge, solid concentrations of only 2 to 3% were achieved at mass loading rates between 30 and 50 kg/sq m/day (6-10 lbs/sq ft/day). These values compared to approximately 8% solids at mass loading rates up to 100 kg/sq m/day (100 lbs/sq ft/day) for wet-weather primary sludge. The results were poorer for secondary sludge samples where a solids concentration of only 2% or less could be expected at solids loadings below 20 kg/sq m/day (4 lbs/sq ft/day). The dry-weather secondary sludge results were quite similar to the poor gravity thickening results for the wet-weather secondary sludge discussed earlier.

The results of flotation thickening tests are shown in Figures 37 through 39. For primary sludge, scum concentrations of greater than 5% solids could be expected at a mass loading rate of 65 kg/sq m/day (13 lbs/sq ft/day) with the use of 15.6 kg/m ton (31 lbs/ton) of Dow C-31 polyelectrolyte and at a recycle rate of 230%. However, for secondary sludge, use of chemicals did not aid in flotation thickening as shown by a comparison of Figures 38

Table 22. VACUUM FILTRATION TESTING RESULTS FOR NEW PROVIDENCE, NJ, WET-WEATHER TRICKLING FILTRATION PRIMARY SLUDGE

Feed Solids Concentration - 2.5%

Chemical dosage, kg/m ton $FeCl_3$	Chemical dosage, kg/m ton CaO	Cycle time, min	Pickup time, sec	Dry time, sec	Submergence %	Yield, $kg/hr/m^2$	Loading, kg/m^2	Cake solids, %	Filtrate solids, mg/l	Filtrate volume, ml	Type of cloth	Cake Discharge characteristics
54	160	4	60	120	25	13.35	0.89	27.4	116	420	multifilament polypropylene	Good
54	160	6	132	148	37.5	11	1.10	26.9	174	570	multifilament polypropylene	Good
54	160	2	30	60	25	17.7	0.59	27.5	82	265	multifilament polypropylene	Good
54	160	3	66	73	37.5	18.2	0.91	27.8	92	430	multifilament polypropylene	Good
54	160	4	88	98	37.5	17.1	1.14	25.7	85	550	multifilament polypropylene	Good

Table 23. VACUUM FILTRATION TESTING RESULTS FOR NEW PROVIDENCE, NJ, WET-WEATHER TRICKLING FILTRATION SECONDARY SLUDGE

Feed Solids Concentration - 31,500 mg/l

Chemical dosage, kg/m ton		Cycle time, min	Pickup time, sec	Dry time, sec	Submergence %	Yield, $kg/hr/m^2$	Loading, kg/m^2	Cake solids, %	Filtrate solids, mg/l	Filtrate volume, ml	Type of cloth	Cake Discharge characteristics
$FeCl_3$	CaO											
85	254	4	60	120	25	18.45	1.23	18.5	231	460	multifilament polypropylene	Good
85	254	4	88	98	37.5	24.45	1.63	15.7	184	560	multifilament polypropylene	Good
85	254	6	132	148	37.5	16.9	1.69	16.5	188	600	multifilament polypropylene	Good
85	254	2	45	50	37.5	39.6	1.32	13.8	546	265	multifilament polypropylene	Good
85	254	3	66	73	25	34.8	1.74	15.0	441	360	multifilament polypropylene	Good
85	254	5	110	122	25	21.84	1.82	13.5	478	360	multifilament polypropylene	Good

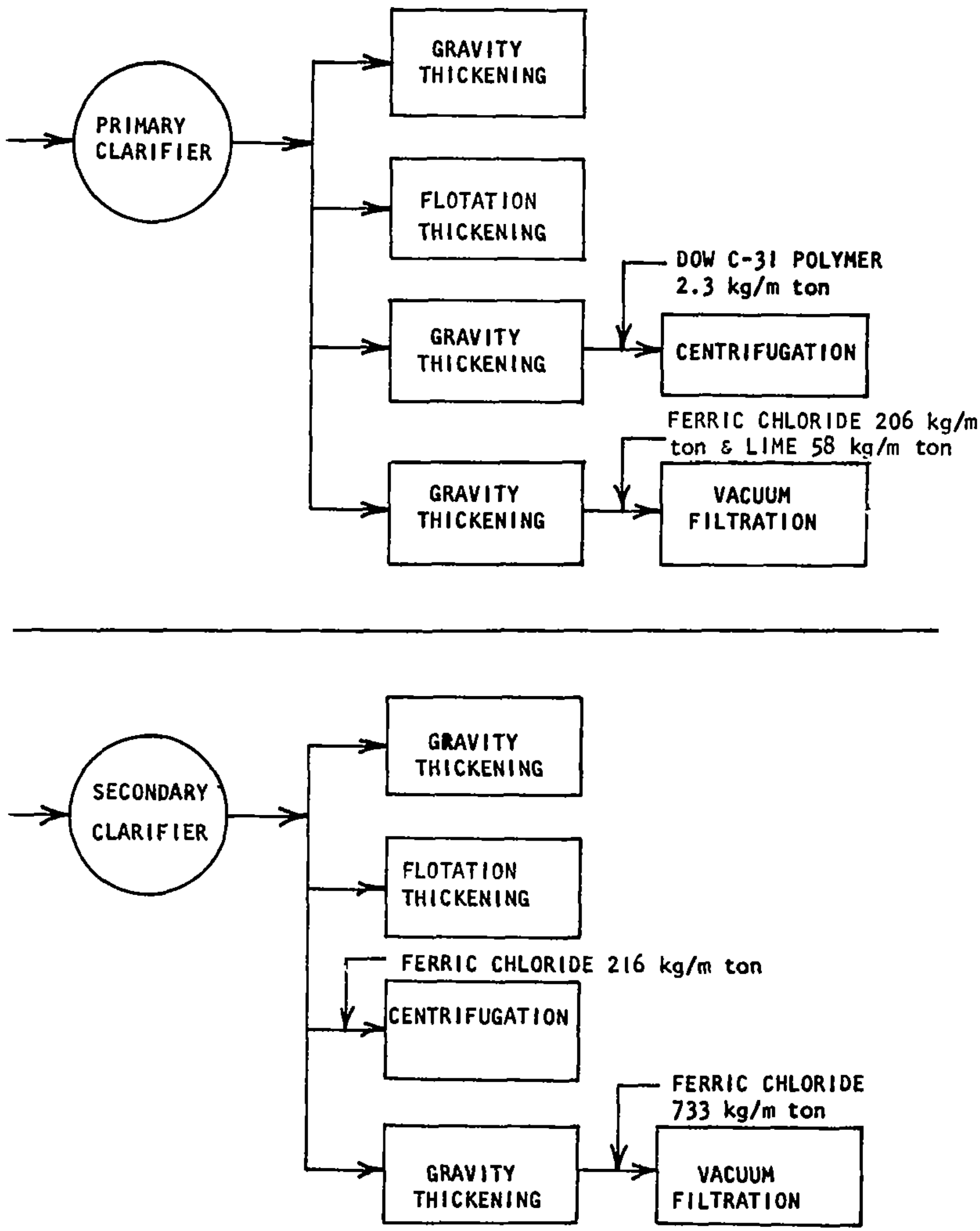

Figure 34. New Providence, NJ - bench scale dewatering tests (dry-weather)

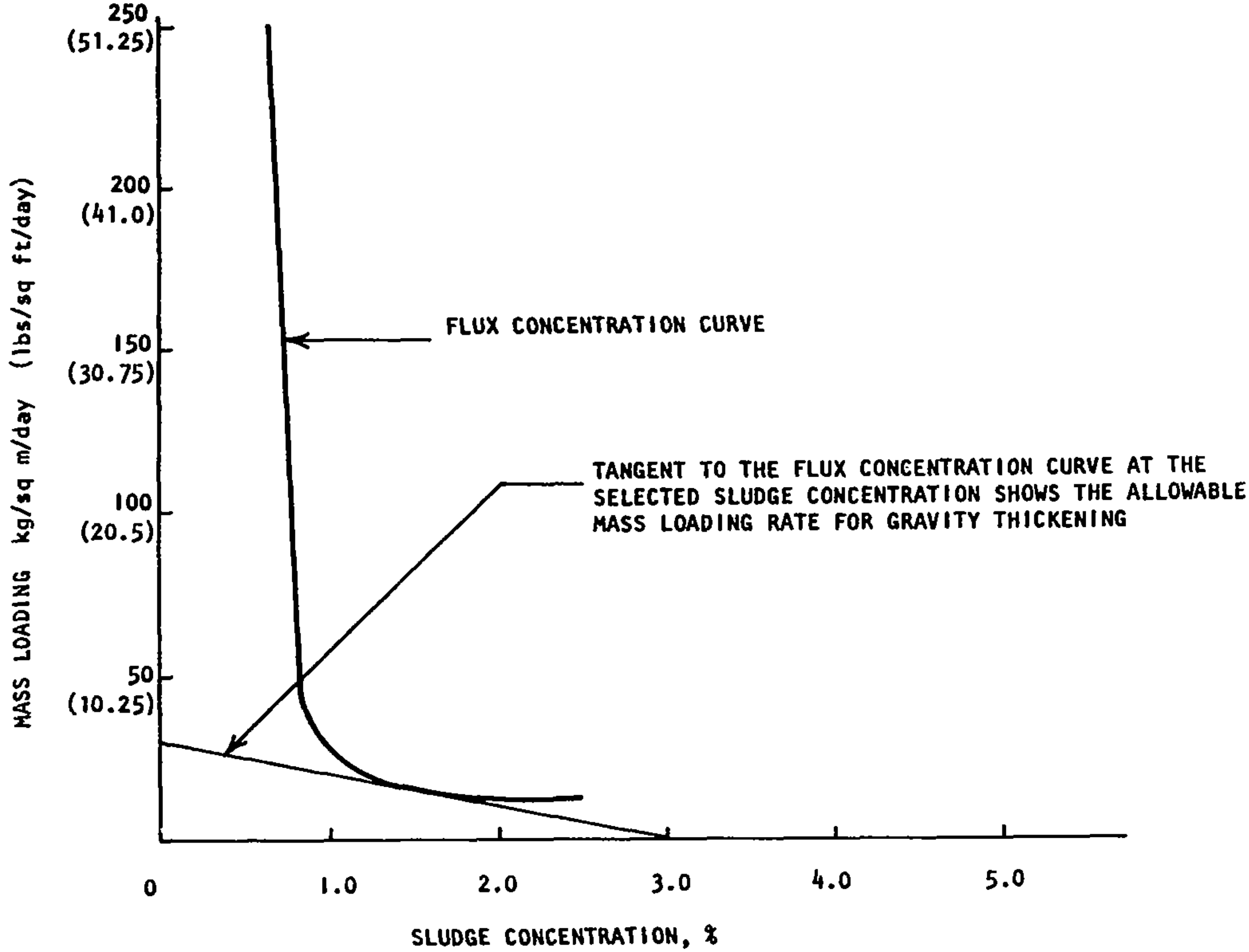

Figure 35. Flux concentration curve for New Providence, NJ, dry-weather primary sludge

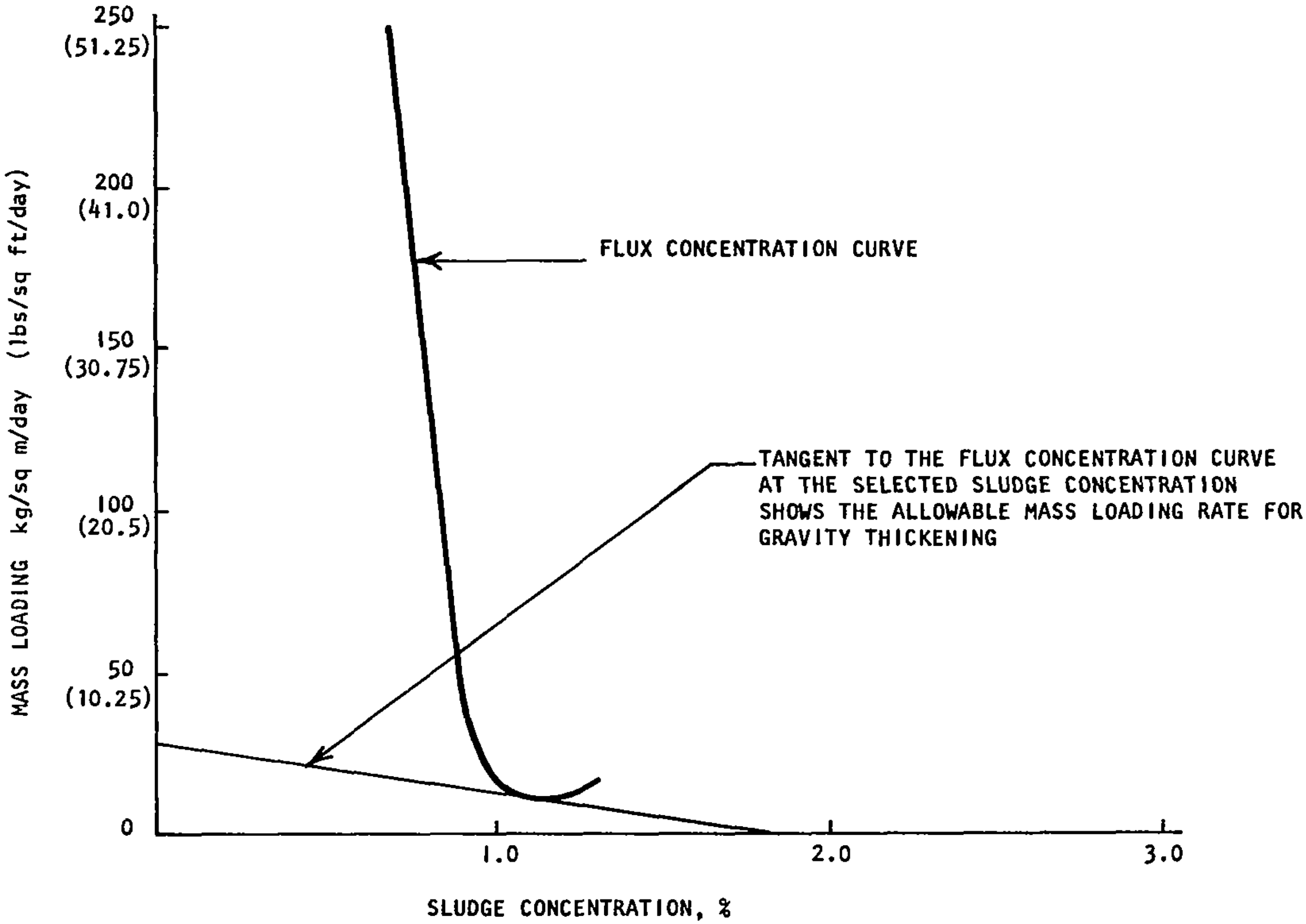

Figure 36. Flux concentration curve for New Providence, NJ, dry-weather secondary sludge

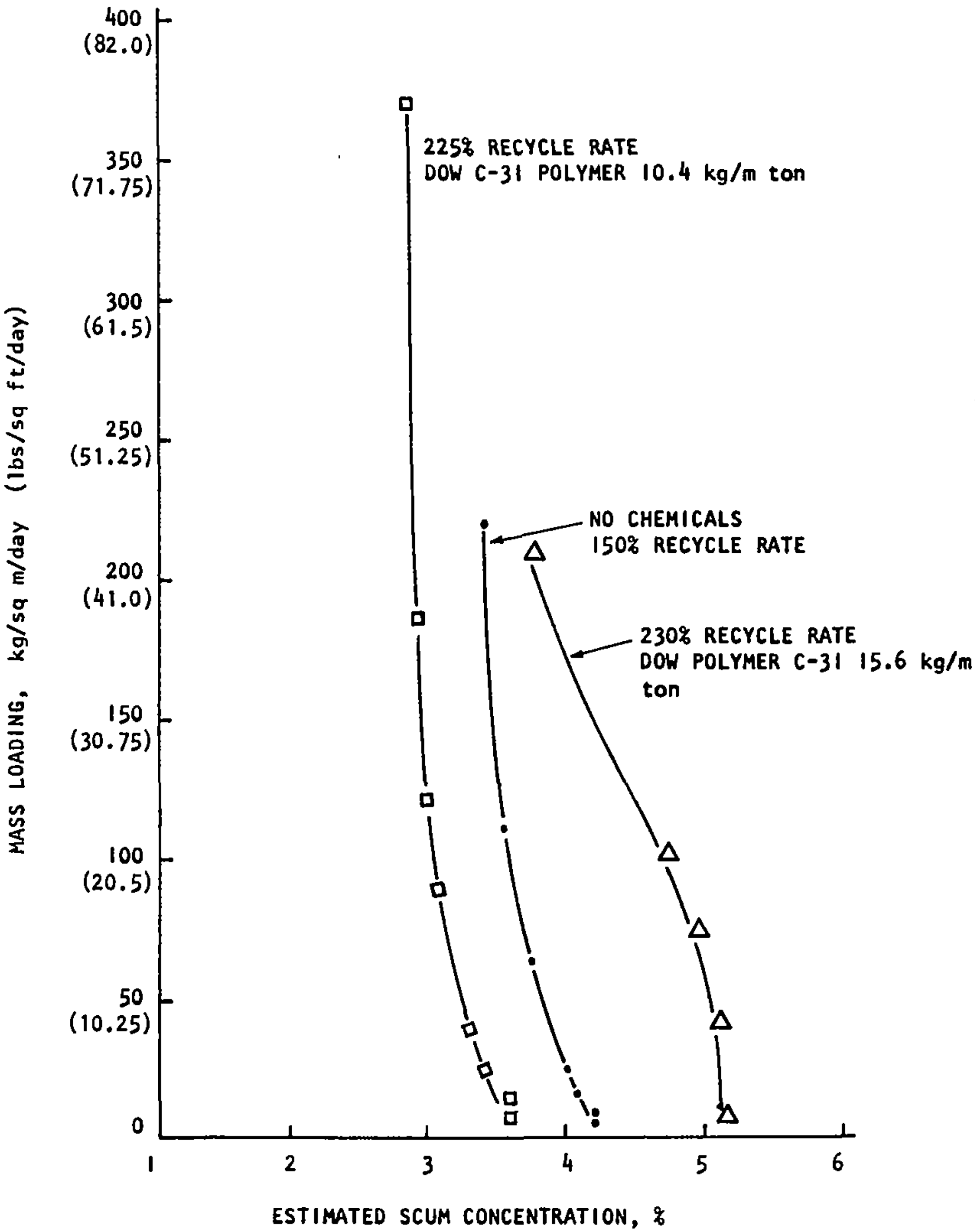

Figure 37. Flotation thickening test results for New Providence, NJ, dry-weather primary sludge

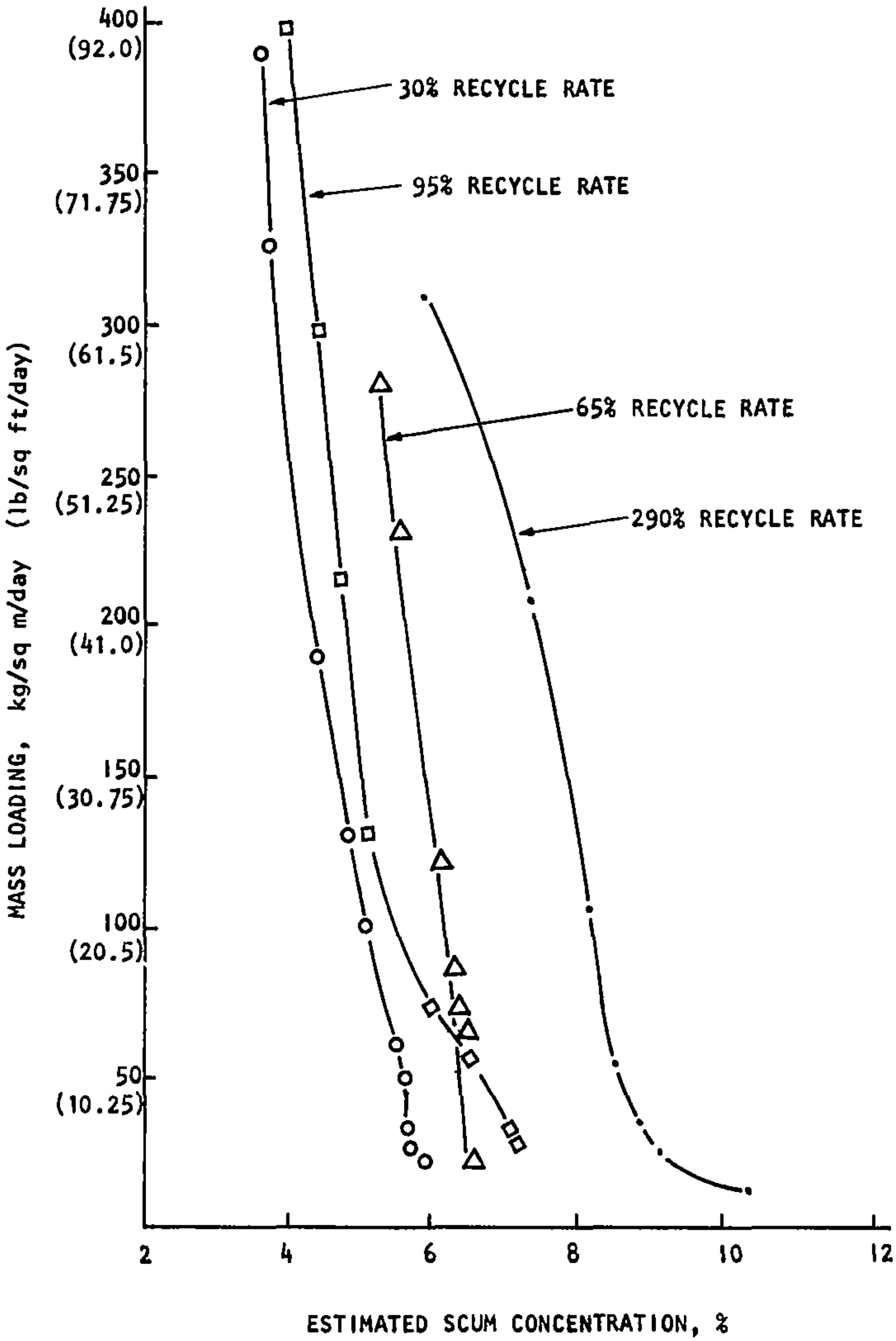

Figure 38. Flotation thickening test results for New Providence, NJ, dry-weather secondary sludge (without chemicals)

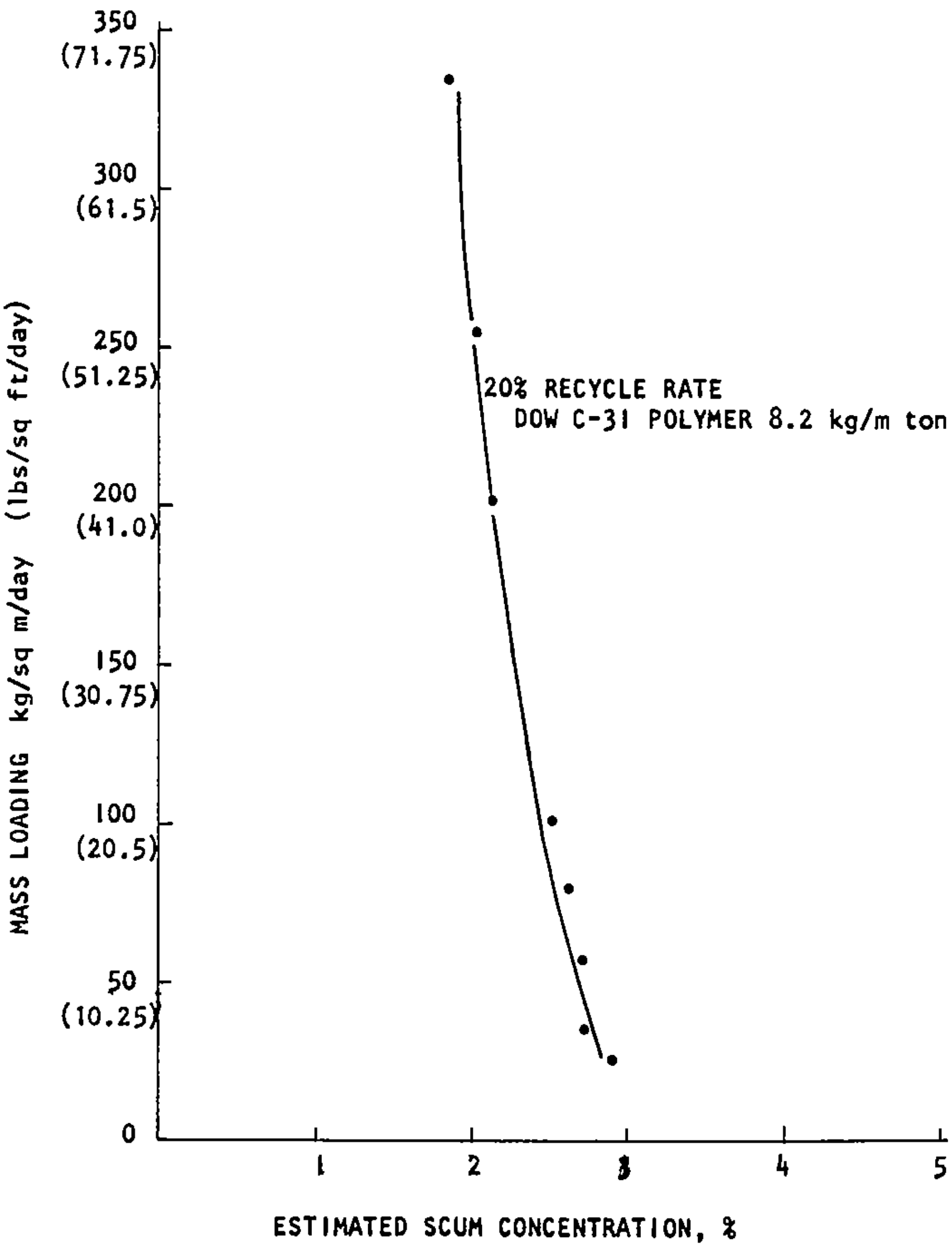

Figure 39. Flotation thickening test results for New Providence, NJ, dry-weather secondary sludge (with chemicals)

and 39. Scum concentrations as high as 8 to 10% solids could be achieved without use of any chemical aids at mass loading rates between 50 and 100 kg/sq m/day (10-20 lbs/sq ft/day). The optimum recycle rates varied between 200 and 300% for the two samples. Again, the dry-weather flotation thickening results were similar to the wet-weather thickening results.

Centrifugation test results are shown in Tables 24 and 25 for the two samples. For the primary sludge sample, these tests were conducted on a presedimented sample at a feed solids concentration of 1.8%. Optimum results were shown without the use of flocculating chemicals and cake solids up to 13% were achieved under optimum test conditions (700 to 1000 G and 60 to 120 seconds spin time). These results are in sharp contrast to the primary sludge samples during wet-weather, and confirm the earlier statement for the primary wet-weather sludge sample whereby it was indicated that significantly improved centrifuge performance may be expected for pre-thickened sludge samples. The tests on the secondary sludge samples were conducted without pre-thickening. Generally poorer results were shown as cake solids of only 2% or less were achieved. However, this performance may again be attributed to the dilute nature of the raw sample and significantly improved results can be expected on pre-thickened samples.

The vacuum filtration tests on both the primary and secondary dry-weather sludge samples were conducted on pre-thickened samples, similar to the wet-weather filtration tests. The feed solids concentrations after sedimentation of the raw samples were 2.6% and 1.9% respectively. The test results are shown in Tables 26 and 27. A chemical combination of lime and ferric chloride again provided optimum filtration results similar to the wet-weather sludge filtration tests. Best cake discharge characteristics were achieved with a 3 x 1, 100% olefin multifilament filter cloth for both the sludges. Cake solids of 20 to 22% for primary sludge and 12 to 14% for secondary sludge were achieved under optimum conditions. The optimum filter yields varied between 13 and 35 kg/sq m/hr (2.6 and 7 lbs/sq ft/hr) for primary sludge and between 10 to 15 kg/sq m/hr (2-3 lbs/sq ft/hr) for the secondary sludge. These results are very similar to the corresponding results for wet-weather sludges and indicate amenability to dual (dry/wet) treatment of sludges.

Treatment Costs for Biological CSO Sludges (Wet-Weather)

A summary of the estimated area and cost requirements of the various dewatering techniques for wet-weather biological treatment sludges is shown in Table 28. Again, the total costs include amortized capital, operating and hauling costs of ultimate residuals as shown in Appendix C. It is evident that for biological sludges, generally, vacuum filtration dewatering in combination with gravity or flotation thickening provided most effective and economic method of handling such sludges. However, the economic results for centrifugation in combination with gravity or flotation thickening were quite close to the corresponding costs for vacuum filtration. Because of the poor scrollability of biological sludges, cost estimates for centrifuges were based on basket type centrifuge units. A more detailed discussion of the overall sludge treatment needs is made in Section VIII of this report after discussion of the bleed back concept in Section VII.

Table 24. CENTRIFUGE TESTING RESULTS FOR NEW PROVIDENCE, NJ, DRY-WEATHER PRIMARY SLUDGE

Test No.	Applied G force, 'G's'	Spin time, sec	Feed solids, mg/l	Chemical	Dosage, kg/m ton	Centrate solids, mg/l	Centrate volume, ml	Penetration, cm	Sludge depth cm	Cake solids, %	Penetration, %	Recovery, %	Corrected recovery, %
1	1,000	120	17,500	None	None	314	65	2.45	2.45	12.9	40	98	90
2	1,000	120	17,500	C31	2.29	267	65	0.9	1.75	13.0	48	98	91
3	1,000	90	17,500	C31	2.29	146	63	1.05	1.75	10.9	40	99	90
4	1,000	60	17,500	C31	2.29	264	64	1.0	2.0	11.8	50	98	91
5	1,000	30	17,500	C31	2.29	480	61	1.4	2.25	9.2	37	97	88
6	700	120	17,500	C31	2.29	132	65	0.9	1.8	13.0	50	99	92
7	700	90	17,500	C31	2.29	188	64	1.2	2.0	11.8	40	99	90
8	700	60	17,500	C31	2.29	246	61	1.0	2.0	9.3	50	99	92
9	700	30	17,500	C31	2.29	510	62	1.45	2.35	9.8	38	97	88
10	400	120	17,500	C31	2.29	200	63	1.1	2.0	10.8	45	99	90
11	400	90	17,500	C31	2.29	290	64	1.4	2.05	11.6	29	98	87
12	400	60	17,500	C31	2.29	250	61	1.9	2.30	9.3	15	99	82
13	700	120	17,500	$FeCl_3$	5.7	94	63	0.75	2.05	10.9	63	99	95
14	700	90	17,500	$FeCl_3$	5.7	130	60	0.85	2.4	8.7	64	99	95
15	700	60	17,500	$FeCl_3$	5.7	122	61	1.1	2.2	9.3	48	99	92
16	700	30	17,500	$FeCl_3$	5.7	158	57	1.3	2.3	7.2	54	99	92
17	400	120	17,500	$FeCl_3$	5.7	156	58	1.3	2.85	7.7	42	99	90
18	400	90	17,500	$FeCl_3$	5.7	146	57	1.45	2.5	7.2	33	99	89
19	400	60	17,500	$FeCl_3$	5.7	292	50	1.65	2.45	5.2	8	98	76
20	400	30	17,500	$FeCl_3$	5.7	142	57	1.3	3.35	7.2	43	99	91

Table 25. CENTRIFUGE TESTING RESULTS FOR NEW PROVIDENCE, NJ, DRY-WEATHER SECONDARY SLUDGE

Test No.	Applied G force, "G's"	Spin time, sec	Feed solids, %	Chemical	Dosage kg/m ton	Centrate solids, mg/l	Centrate volume, ml	Penetration, cm	Sludge depth, cm	Cake solids, %	Penetration, %	Recovery, %	Corrected recovery, %
21	1,000	120	4,620	None	None	334	53	2.75	2.75	1.5	0	93	0
22	1,000	120	4,620	$FeCl_3$	21.6	128	54	2	3.0	1.6	33	96	86
23	1,000	90	4,620	$FeCl_3$	21.6	116	53	2.5	2.85	1.5	12	97	78
24	1,000	60	4,620	$FeCl_3$	21.6	98	51	3.1	3.1	1.4	0	98	0
25	1,000	120	4,620	$FeCl_3$	500	120	59	1.05	2.8	2.1	62	97	92
26	1,000	90	4,620	$FeCl_3$	500	74	52	1.25	2.85	1.5	56	98	92
27	1,000	60	4,620	$FeCl_3$	500	130	52	2.15	3.05	1.5	20	97	83
28	1,000	30	4,620	$FeCl_3$	500	108	49	3.05	3.05	1.3	0	98	0
29	1,000	120	4,620	C-31	12.9	325	55	3.0	3.0	1.6	0	93	0
30	1,000	120	4,620	$FeCl_3$	216	194	62	1.35	2.8	2.6	52	96	90
31	1,000	60	4,620	$FeCl_3$	216	175	59	2.1	2.85	2.1	26	96	83
32	1,000	30	4,620	$FeCl_3$	216	228	57	3.3	3.3	1.8	0	95	0
33	1,000	30	4,620	$FeCl_3$	1,080	112	44	3.5	3.5	1.1	0	98	0
34	1,000	120	4,620	$FeCl_3$	216	92	54	1.25	2.85	1.6	56	98	92
35	1,000	90	4,620	$FeCl_3$	216	104	53	2.05	3.1	1.5	34	98	88
36	1,000	60	4,620	$FeCl_3$	216	106	52	2.45	3.2	1.5	25	98	85
37	1,000	30	4,620	$FeCl_3$	216	134	47	3.55	3.55	1.2	0	97	0
38	700	120	4,620	$FeCl_3$	216	114	53	1.4	3.05	1.5	54	98	92
39	700	90	4,620	$FeCl_3$	216	128	52	1.60	3.4	1.5	44	[illegible]	89
40	700	60	4,620	$FeCl_3$	216	162	49	3.95	3.45	1.3	13	96	78
41	700	30	4,620	$FeCl_3$	216	320	44	4.0	4.0	1.1	0	93	0
42	400	120	4,620	$FeCl_3$	216	164	50	2.15	3.4	1.4	37	96	67
43	400	90	4,620	$FeCl_3$	216	198	46	3.65	3.65	1.2	0	96	0
44	400	60	4,620	$FeCl_3$	216	192	47	3.9	3.9	1.2	0	96	0
45	400	30	4,620	$FeCl_3$	216	396	33	5.3	5.3	0.8	0	91	0

Table 27. VACUUM FILTRATION TESTING RESULTS FOR NEW PROVIDENCE, NJ, DRY-WEATHER SECONDARY SLUDGE

Feed Solids Concentration - 1.9%

Chemical dosage, kg/m ton		Cycle time, min	Pickup time, sec	Dry time, sec	Submergence, %	Yield, $kg/hr/m^2$	Loading, kg/m^2	Cake solids, %	Filtrate solids, mg/l	Filtrate volume, ml	Type of cloth	Cake Discharge characteristics
$FeCl_3$	CaO											
620	0	5	110	122	37.5	7.48	0.62	9.8	67	430	3 X 1 twill olefin 100% multifilament	Poor
620	0	5	75	150	25	7.38	0.61	10.3	41	360	3 X 1 twill olefin 100% multifilament	Good
620	0	3	45	90	25	9.92	0.49	10.1	47	240	3 X 1 twill olefin 100% multifilament	Fair
733	0	5	75	150	25	7.09	0.59	11.5	37	400	3 X 1 twill olefin 100% multifilament	Good
733	0	4	60	120	25	7.66	0.51	13.2	21	285	3 X 1 twill olefin 100% multifilament	Good
567	212	5	75	150	25	6.23	0.52	12.6	166	355	3 X 1 twill olefin 100% multifilament	Good
567	212	4	60	120	25	8.73	0.58	12.8	79	335	3 X 1 twill olefin 100% multifilament	Good
567	212	3	45	90	25	15.16	0.78	13.6	51	445	3 X 1 twill olefin 100% multifilament	Good
567	212	2	30	60	25	16.86	0.56	12.9	73	340	3 X 1 twill olefin 100% multifilament	Good
567	212	3.5	30	120	14	11.46	0.66	13.8	45	365	3 X 1 twill olefin 100% multifilament	Good

Table 28. SUMMARY OF AREA AND COST REQUIREMENTS FOR WET-WEATHER BIOLOGICAL SLUDGES UNDER OPTIMUM TREATMENT CONDITIONS

Site.	Kenosha, WI				New Providence, NJ							
					Primary sludge				Secondary sludge			
	Sludge solids, %	Area, sq ft	Area, (sq m)	Total annual cost[a], $/yr	Sludge solids, %	Area, sq ft	Area, (sq m)	Total annual cost[a], $/yr	Sludge solids, %	Area, sq ft	Area, (sq m)	Total annual cost[a], $/yr
Gravity Thickening	1	1593	(148)	520,700	8	172	(16)	21,100	4	732	(68)	59,900
Flotation Thickening	3	463	(43)	186,600	6	151	(14)	32,500	4	355	(33)	59,700
Centrifugation	9	205	(19)	90,100	13[b]	205	(19)	24,300	7.5	54	(5)	39,300
Vacuum Filtration	15[b]	614	(57)	79,800	27.5[b]	323	(30)	18,600	18.5[b]	581	(54)	35,300

a. Capital costs amortized for 20 year equipment life and 10% interest rate. For details of cost estimates, see Appendix C.

b. These tests conducted on gravity or flotation thickened sludge.

All costs based on December, 1974 prices.

Table 26. VACUUM FILTRATION TESTING RESULTS FOR NEW PROVIDENCE, NJ, DRY-WEATHER PRIMARY SLUDGE

Feed Solids Concentration - 2.6%

Chemical dosage, kg/m ton		Cycle time, min	Pickup time, sec	Dry time, sec	Submergence, %	Yield, $kg/hr/m^2$	Loading, kg/m^2	Cake solids, %	Filtrate solids, mg/l	Filtrate volume, ml	Type of cloth	Cake Discharge characteristics
$FeCl_3$	CaO											
206	58	5	75	150	25	18.5	1.55	22.8	73	830	3 X 1 twill olefin 100% multifilament	Blinds
206	58	2	30	60	25	33.8	1.13	20.1	84	470	3 X 1 twill olefin 100% multifilament	Poor
206	38	2	30	60	25	34.08	1.13	21.5	68	555	3 X 1 twill olefin 100% multifilament	Good
103	58	2	30	60	25	28.04	0.93	14.5	263	175	3 X 1 twill olefin 100% multifilament	Poor
154	58	2	30	60	25	12.54	0.41	17.2	117	330	3 X 1 twill olefin 100% multifilament	Good

SECTION VII

PUMPBACK/BLEEDBACK CONCEPT AND ITS APPLICABILITY

The determination of the efficiency of various sludge thickening and dewatering techniques for treating the sludges arising from combined sewer overflow treatment processes has been the main thrust of this research activity. However, the feasibility of actually pumping back or bleeding back these on-site sludges to existing dry-weather treatment facilities must also be considered. By controlled pumpback or bleedback of the CSO treatment residuals, additional cost of the on-site sludge treatment facilities may be avoided or minimized. At the dry-weather treatment plant, the diluted sludge can then be removed in the grit removal, primary sedimentation, or secondary treatment processes and become part of the treatment plant sludge.

In cases where the combined sewer overflow treatment facilities are located on the grounds of the municipal wastewater treatment plant, the question that has to be resolved is whether the existing sludge handling facilities (perhaps with unused capacity) can be used for the combined sewer overflow treatment sludges, or if separate facilities of a different type have to be constructed.

A typical mode of operation of a pumpback or a bleedback system would consist of monitoring instrumentation that would measure the flow rate and solids handling capacity at the treatment plant and feed this information back to the sludge holding facilities. When the capacity at the treatment plant is sufficient, the tanks automatically drain, or are pumped if necessary, to the interceptor sewer. Any significant increase in the flow rate at the treatment plant due to a rainfall or any other cause would be sensed and the sludge draining would cease.

LOADING ON THE DRY-WEATHER PLANT

When the sludge enters the sewerage system it will be diluted significantly by the dry-weather flow. The resultant increase in suspended solids concentration at the dry-weather plant will be a function of the 1) concentration of the sludge itself, 2) the amount and rate of sludge draining, 3) the dry-weather sewage suspended solids concentration, and 4) the dry-weather flowrate.

The primary effect on the treatment plant once the sludge has reached the treatment plant will be measured by 1) the change in hydraulic loading, 2) the change in grit and solids loading, and 3) the effect of slug loadings of toxic materials such as heavy metals or pesticides on the treatment processes (especially biological). The secondary effect on the treatment plant is 1) the increased sludge production which must be handled by the existing solids handling facilities and 2) the possibility of any disruption of the digestion process due to any slugs of heavy metals or pesticides or even grit if it were to get past the grit chambers into the primary sedimentation tanks.

To illustrate the pumpback/bleedback concept a hypothetical example is presented. Listed below are the criteria for a typical city, assuming that some type of combined sewer overflow treatment facility exists along with a conventional activated sludge treatment plant for dry-weather flow.

Sewered population	100,000 persons
Treatment plant design capacity	94,625 cu m/day (25 mgd)
Average daily flow	75,700 cu m/day (20 mgd)
Gross digestion volume	7400 cu m (300,000 ft^3)
Sewered area	4050 ha (10,000 acres)
Combined sewer area	2025 ha (5000 acres)
Overflow from a 2.5 cm (1.0 in) rain*	246,025 cu m (65 million gallons)
Sludge produced (assuming 200 mg/l solids removed)	49,485 kg (109,000 lbs)
Sludge volume at 2% concentration	2460 cu m (0.65 million gallons)

* Assuming approximately 50% of the rainfall results in overflow.

If the 2460 cu m (0.65 million gal.) were bled back to the treatment plant at a constant rate over a 24 hour period, this would be an average increase in flow rate of only 3.25%. However, the average increase in solids loading would be 338%. Figure 40 contains two graphs, the top shows a typical dry weather diurnal flow pattern with the additional flow due to the bleedback also shown. The bottom graph shows the dry-weather solids loading and the solids loading due to bleedback. A constant raw suspended solids value of 200 mg/l was used in determining the dry-weather solids loading.

The significant fact in Figure 40 is that although the increase in hydraulic loading at the dry-weather treatment plant is negligible, the solids loading is significant. Based on the hypothetical data used to calculate the graphs in Figure 40, the average suspended solids concentration in the raw flow during the period of bleedback would be 870 mg/l. If this concentration would cause significant solids deposition in the sewerage system, or if the added solids would be in excess of what the dry-weather plant facilities could handle, then bleedback would not be feasible. It may be possible to increase the duration of bleedback to reduce the rate of solids loading but there are limits on this time because of possible problems with sludge septicity, odors, necessity of aeration, and reduced amenability to certain thickening processes.

The possibility of settling occurring in the sewerage system during pump/bleedback will obviously depend on the hydraulic situation in the sewer to which the

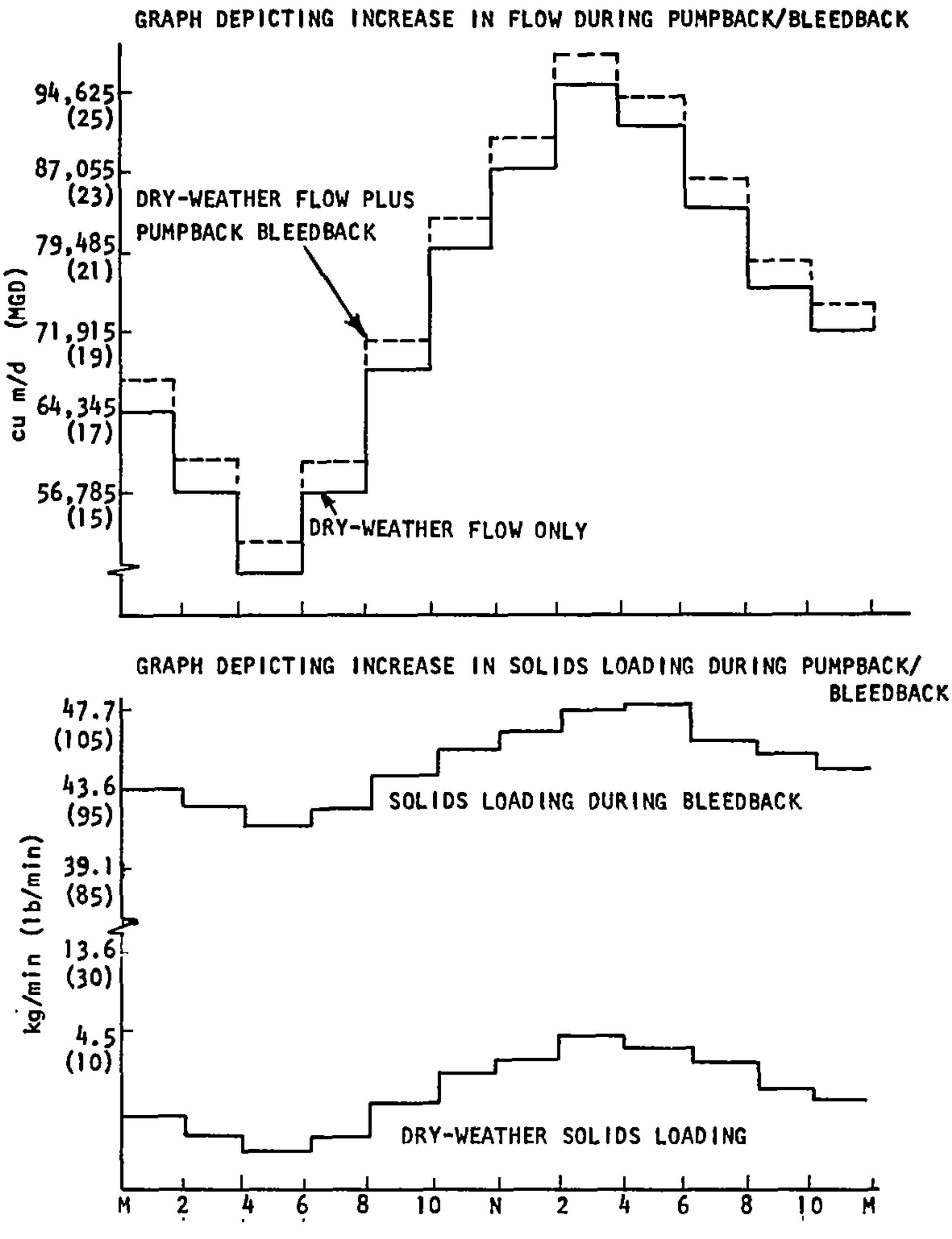

Figure 40. Graphs depicting the increase in hydraulic loading (top) and solids loading (bottom) during pumpback/bleedback to the treatment plant

produced sludge is pumped or bled. It is common practice for most sewers to be designed with a velocity of at least 0.6 cm/s (2 fps) to prevent solids deposition. However, in larger interceptor sewers at low flow, velocities can go below 0.6 cm/s (2 fps). In addition, particles having specific gravities significantly greater than 1.0 and with relatively large diameters require velocities in excess of 0.6 cm/s (2 fps) to prevent settling. The velocity required to keep a particle in suspension is a function of both particle specific gravity and diameter as designated below (23).

$$\text{Required velocity} = \sqrt{\frac{8B}{f} g\ (s-1)\ Dg}$$

where: B = dimensionless empirical constant
f = friction factor (0.025 for a full pipe)
g = acceleration due to gravity
s = specific gravity
Dg = particle diameter to be transported

It should be noted that required velocities to keep a particle in suspension change 1) with a change in diameter at a constant specific gravity and 2) with a change in specific gravity at a constant diameter. In many cases velocities of greater than 0.6 cm/s (2 fps) can be required, and these instances may arise with sludge being drained back to the sewerage system. Actual velocities required to keep materials in suspension have been determined. Table 29 has been developed by the American Society of Civil Engineers and contains the various velocities required to prevent deposition of materials, some of which may be analogous to sludge being pumped or bledback (23,24)

Table 29. VELOCITIES REQUIRED TO PREVENT SOLIDS DEPOSITION

Material	Clear water		Water transporting colloidal silts	
	m/s	f/s	m/s	f/s
Fine sand, non-colloidal	0.457	1.50	0.762	2.50
Sandy loam, non-colloidal	0.533	1.75	0.762	2.50
Silt loam, non-colloidal	0.609	2.00	0.914	3.00
Alluvial silts, non-colloidal	0.609	2.00	1.067	2.50
Ordinary firm loam	0.762	2.50	1.067	3.50
Fine gravel	0.762	2.50	1.524	5.00
Stiff clay, very colloidal	1.14	3.75	1.524	5.00
Alluvial silts, colloidal	1.14	3.75	1.524	5.00

Even if the excess solids passed through the sewerage system and settled in primary sedimentation, and a concentration of 5% were achieved, it is doubtful that this amount of sludge could be removed. At 5% this would amount to a volume of 980 cu m (35,000 ft^3), and if pumped to the digester in a 24 hour period this would displace over 10% of the digester contents. This does not include the additional solids that may be produced in secondary treatment by conversion of the soluble BOD associated with the pump/bleedback into biomass. Furthermore, as pointed out earlier in this report, the volatile percentage of the sludges produced at these combined sewer overflow treatment sites appears to be below 60%. This means that the digestion of this material will probably be very inefficient and have a minimum impact on reducing the putrescibility of the sludge.

Obviously, the hypothetical example discussed here is applicable only to itself. Each application will be unique and must be studied as such. In some applications the combined sewer area may be a smaller portion of the total area and the additional solids loading would not be a significant addition, or perhaps in some applications the primary removal and sludge handling facilities may be sufficient to handle the increased load. It should also be remembered that even if the present sludge handling facilities at the dry-weather treatment plant are of insufficient capacity, it may be more economical from a capital and operating cost perspective to build additional facilities at the dry-weather plant rather than at the combined sewer overflow treatment site.

TOXICITY CONSIDERATIONS

Toxicity to a biological treatment system as a result of pumpback/bleedback of sludges produced from combined sewer overflow treatment must also be considered. The primary concern is the heavy metals and pesticides which are concentrated in the sludge. It is difficult to determine what the specific limiting values of certain heavy metals entering a sewage treatment plant would be. The toxicity can be reduced by other chemicals which may precipitate the metals, form organo-metallic compounds, or by combining with other metals to have an antagonistic effect. Conversely the toxicity may be increased by other cations having a synergistic effect (25,26).

Many articles on the subject of metal toxicity to biological treatment processes have appeared in the literature. Since most data were developed in laboratory tests, some for continuous operations and some for batch, there is a variance in reported values. It has been reported (25) that for sewage treatment bacteria (as found in the activated sludge process) silver and nickel are the most toxic to sewage bacteria, with no bacterial growth occurring above 25 mg/l of either element. Copper and chromium were found to have no effect on sewage bacteria in concentrations lower than 25 mg/l, but were highly toxic at 100 mg/l. Zinc toxicity was considered moderate, with no toxicity effects at less than 100 mg/l concentrations.

Barth, et al (27) conducted extensive laboratory tests simulating an activated sludge plant. Reductions in aerobic treatment efficiency on a continuous dose basis were found at the levels listed below. It was also concluded that the activated sludge process could tolerate, with only about a 5% decrease in efficiency, concentrations of chromium, copper, nickel and zinc up to 10 mg/l, either singly or in combination. An interesting finding of this study was that although the threshold levels (those concentrations at which an effect on treatment can be noticed) may be low, e.g. 1-2 mg/l, there is a plateau effect being realized for a manifold increase in concentration. Figure 41 illustrates this point.

Metal	Concentration in influent sewage
Hexavalent chromium	10 mg/l
Copper	1 mg/l
Nickel	1-2.5 mg/l
Zinc	5-10 mg/l

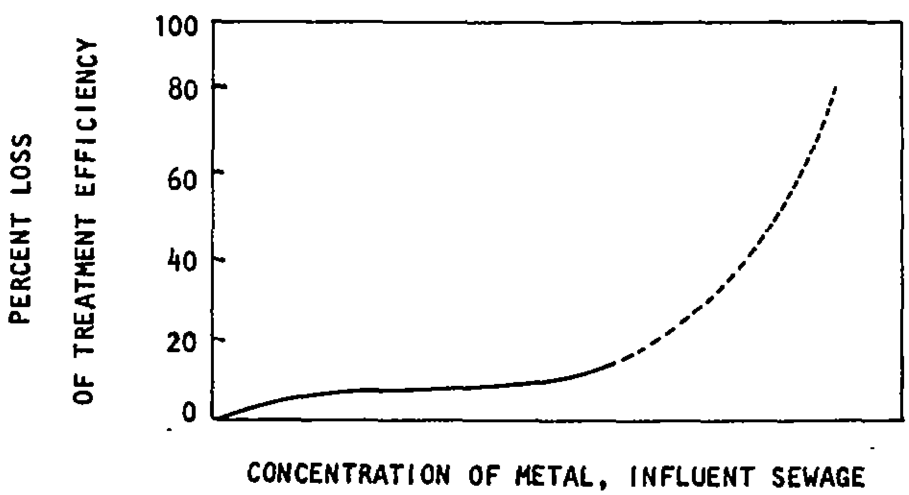

Figure 41. Response of System to Metal Dosage

The effects of sludge doses of four hour duration were also determined in this study by raising influent concentrations for four hours and measuring the decrease in effluent quality. The maximum sludge doses that could be tolerated were found to be:

Metal	Concentration in influent sewage
Hexavalent chromium	>500 mg/l
Copper	75 mg/l
Nickel	>50 -<200 mg/l
Zinc	160 mg/l

TABLE 31. DISTRIBUTION OF METALS THROUGH THE ACTIVATED SLUDGE PROCESS (CONTINUOUS DOSAGE)

	Outlet	Cr (VI) (15 mg/l)	Cu (10 mg/l)	Ni (10 mg/l)	Zn (10 mg/l)
Percent of metal fed	Primary sludge	2.4	9	2.5	14
	Excess activated sludge	27	55	15	63
	Final effluent	56	25	72	11
	Metal unaccounted for	15	15	11	12
	Average efficiency of process in removing metal	44	75	28	80
	Range of observations	18-58	50-80	12-76	74-97

Other reported metal toxicity levels to the activated sludge process from various studies include 10 mg/l for nickel (28) and 16.0 mg/l for nickel ($NiSO_4$), 0.40 mg/l for copper ($CuSO_4$), and 0.23 mg/l for chromium ($CrCl_2$) (29). Although chromium has been the subject of many toxicity studies (30,31,32), a wide range of values have been reported at the maximum allowable limits, e.g. up to 250 mg/l. However, it is agreed that reduced chromium has little effect on treatment and that hexavalent chromium is toxic, but at much higher concentrations than the other common heavy metals.

A notable effect reported in most studies is the inhibition of nitrification by the heavy metals. Values in the range of 1-2 mg/l of metals, even though not toxic, may completely stop nitification. This could have an important effect on any breakpoint chlorination step that would follow final settling or the oxygen demand on the receiving body of water when nitrification begins.

Just as important and perhaps even more critical than the effect of the heavy metals on treatment is the effect on digestion. Limits of 1 mg/l for copper, cyanide, and chromium, and 2.5 mg/l for zinc and nickel have been recommended as maximum concentrations for raw sewage subject to sludge digestion (33). Table 30 illustrates the various reported maximum limits for raw sewages subjected to sludge digestion.

Table 30. TOXIC LIMIT FOR METALS IN RAW SEWAGE SUBJECT TO SLUDGE DIGESTION (34)

Reference No.[a]	1	2	3[b]	4	5	6	7	8	9
Metal, mg/l									
Chromium	5.0	5.0	0.05			1.0		1.5	
Cyanide	2.0	1.0	0	0.1	1-1.6				
Copper	1.0	1.0	0.30	0.2		1.0	0.7		
Iron	5.0								
Zinc		5.0	0.3	0.3					>5.0
Nickel			2.0						

a. See Reference 34 for references.
b. For streams and sewers.

Various sources (32,34,35) have noted that heavy metals in the feed to a digester will concentrate in the digested sludge. It appears that when concentrations approach the 1000 mg/l level of heavy metals, digester failure may be realized. The Barth study (27) mentioned earlier traced the fate of heavy metals through the activated sludge process and the results are summarized in Table 31.

TABLE 31. DISTRIBUTION OF METALS THROUGH THE ACTIVATED SLUDGE PROCESS (CONTINUOUS DOSAGE)

	Outlet	Cr (VI) (15 mg/l)	Cu (10 mg/l)	Ni (10 mg/l)	Zn (10 mg/l)
Percent of metal fed	Primary sludge	2.4	9	2.5	14
	Excess activated sludge	27	55	15	63
	Final effluent	56	25	72	11
	Metal unaccounted for	15	15	11	12
	Average efficiency of process in removing metal	44	75	28	80
	Range of observations	18-58	50-80	12-76	74-97

This same study listed the highest allowable dosages for raw feed to anaerobic digestion as follows:

Metal	Primary sludge	Primary and secondary sludge
Hexavalent chromium	>50 mg/l	>50 mg/l
Copper	10 mg/l	5 mg/l
Nickel	>40 mg/l	>10 mg/l
Zinc	10 mg/l	10 mg/l

One of the most important conclusions relative to the question of the feasibility of bleeding combined sewer overflow treatment sludges containing heavy metals back to the treatment plant is the fact that if a digester fails, it completely fails. Unlike the activated sludge process which can have a reduction in efficiency caused by the presence of metals, the anaerobic digestion process will continue to operate at very close to normal efficiencies until the critical level has been reached at which point digester failure will occur.

Table 32 has been developed showing the concentrations of certain heavy metals in the sludges resulting from treatment at the various combined sewer overflow sites. As seen by the data in Table 32 some of the sludges do contain heavy metals in excess of the toxic concentrations discussed earlier. If these sludges are bled back to the treatment plant resulting in a significant concentration dilution, the toxicity dangers are greatly reduced. However, it must also be realized that the above sludge samples only represent one event from each site and are not truly representative of a complete year of operation. In addition, the synergistic effect of these various metals cannot be fully predicted nor can the effect of the possible shock loading on the biological treatment process be predicted without the use of empirical methods. These types of methods are strongly recommended when the concept of sludge pump/bleedback is being considered.

Therefore, it is indicated that it may be more feasible to thicken and dewater the sludge on site rather than pump/bleedback these residuals to the treatment plant. However, the problem of ultimate disposal remains. If it is found that a sludge can be brought up to a 20% solids concentration, the transportation costs of conveying this sludge to a place of ultimate disposal will be greatly reduced. However, this is based on the assumption that the sludge can be disposed of without any form of digestion. If digestion of some type is required (e.g. anaerobic digestion, heat treatment, wet oxidation) then the logistics of concentrating the solids, followed by transport to a digestion process, followed by further dewatering become questionable. Therefore, on the following pages the combined sewer overflow treatment site studies are analyzed for the feasibility of on-site treatment of the residual sludges resulting from treatment as compared to solids pump/bleedback or other alternatives.

Table 32. HEAVY METAL CONCENTRATIONS IN THE SLUDGES RESULTING FROM COMBINED SEWER OVERFLOW TREATMENT

Site	Type of treatment	Type of sludge	Total solids mg/l	Zinc mg/l	Zinc mg/kg	Lead mg/l	Lead mg/kg	Copper mg/l	Copper mg/kg	Nickel mg/l	Nickel mg/kg	Chromium mg/l	Chromium mg/kg	Mercury mg/l	Mercury mg/kg
Racine, WI	Screening/Dissolved Air Flotation	Backwash and	9769	16.0	1638	10.0	1023	4.7	481	2.1	215	2.1	215	0.022	2.3
Hawley Road, Milw., WI	Screening/Dissolved Air Flotation	Float	42700	36.5	855	7	164	10.2	248	7.4	173	6.4	150	0.09	2.1
San Francisco, California	Dissolved Air Flotation	Float	2400	17	708	38	1583	8.9	367	<2	<83	40	1667	0.093	3.9
Philadelphia, Pennsylvania	Screening	Backwash	8660	10.3	1189	21.2	2448	1.73	200	2.5	289	0.45	52	0.018	2.1
Kenosha, WI	Contact Stabilization	Return Activated	8527	61	7154	4.5	528	12.4	1454	4.5	528	10.9	1278	0.022	2.6
New Providence, New Jersey	Trickling Filter	Primary Sedimentation	2010	1.4	694	<1	<498	2	995	2	995	1.5	746	0.202	100
		Secondary Clarification	25500	33	1294	9	353	26	1020	20	784	63	2471		
Humboldt Ave. Milw., WI	Storage Tank w/Mixing	From Settling Test	18900	15.1	799	39	2063	3.8	201	3	159	4.6	243	0.051	2.7
Cambridge, Massachusetts	Storage	Settled in Tank	126,900	120	496	160	1261	96	757	16	126	33	260	1.55	0.01